U. S. DEPARTMENT OF AGRICULTURE.

REPORT

OF THE

CHIEF OF THE FORESTRY DIVISION

FOR

THE YEAR 1889.

AUTHOR'S EDITION.

FROM THE ANNUAL REPORT OF THE DEPARTMENT OF AGRICULTURE FOR THE YEAR 1889.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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REPORT OF THE CHIEF OF FORESTRY DIVISION.

SIR: I have the honor herewith to submit my fourth annual report on the work of the Forestry Division.

As I have pointed out in my former reports, neither the facilities nor the present organization of the division are adequate for such work as is required and would be justified by the importance and magnitude of the interests which could be subserved by this division. Conceived simply as a bureau of information, the facilities for obtaining the information under Government methods have hitherto been insufficient; the amounts appropriated, while unnecessarily large for a simple correspondence bureau, have never been large enough to undertake and carry through any extensive and systematic investigations such as are needed, such as can only be carried on under Government control and are worthy of governmental effort.

Hampered by the inability to command and compensate the service of competent co-workers and without sufficient assistance, all efforts to build up in a systematic manner the work of the division, as outlined in my report for 1887, had to be deferred. Whatever of value has been produced in the division must be credited to the personal interest and effort of individual workers beyond any compensation that could be offered to them, and not to superior organization and facilities such as might have been expected.

As I shall show further on, there is no room for doubt as to what kind of work this division should engage upon, as soon as it is properly equipped and endowed with sufficient appropriations. Pending the absence of such provisions, the work can only remain preparatory and crude, unsatisfactory to those who have a conception of the needs of forestry in this country.

The most promising and satisfactory investigation which has been completed during the year has concerned itself with railroad interests in forest supplies, and especially with the prospects of substituting metal ties for wooden ones. The success of this latter investigation, which will result in presenting a complete history of the experiences with metal ties in all countries, is due to the indefatigable industry and devoted attention to the subject of Mr. E. E. Russell Tratman, civil engineer, whose preliminary report, issued during the year in Bulletin 3, will be followed by a full account, with all desirable detail, such as can not be found collected in any other literature or language.

The appreciation which even the preliminary report has received both in this country and abroad will amply justify the attention given to this special line of inquiry.

While one English technical journal has copied the report verbatim, the London "Industries" in reviewing it uses the following language:

> We would hardly look for "light and leading" on this subject from such a source; but it is nevertheless a fact that probably the most comprehensive statement that has hitherto appeared relative to the substitution of metal for timber for railway purposes has emanated from a department that is only interested in the matter in so far as the forests of the United States are concerned.

That this publication has been timely and has done its share in stimulating our railroad engineers to begin experimenting with metal ties on a large scale may be estimated from the frequent calls for copies by railroad managers, which made a second edition of the Bulletin necessary. As will appear in the full report in Bulletin 4, several railroads in this country have since put, experimentally, a larger number of metal ties on their tracks, while the mileage on metal ties in use in foreign countries exceeds 25,000 miles.

A canvass among our railroad managers in regard to supplies, prices, etc., of wooden ties has also been made and the results will be presented in comparison with a similar canvass made by the division seven years ago, thus showing the change of conditions, if any, in the various localities.

The magnitude of this special drain on forest supplies, which it will be remembered amounts to at least 500,000,000 cubic feet of timber—and that of the thriftiest and most valuable—as well as the appreciation which has been shown on the part of the railroad companies in this canvass by furnishing desired information, may justify the prominence given to this interest.

In passing, it may be mentioned that as a result of circulars issued by the Department through this division, the employment for ties of chestnut oak, which formerly had remained unused in the woods after the tanbark had been stripped off, is reported from those localities where the former wasteful practice existed.

A canvass has been instituted into the needs of the cooperage industry, which uses probably not less than 250,000,000 cubic feet of wood bona fide, and a large amount in addition on account of wasteful methods. For the State of Tennessee this canvass has been completed by the special agent appointed for this division from that State, showing a bona fide consumption of 10,000,000 cubic feet of wood for cooperage while, with the few exceptions where it is made into cord-wood, the remainder of the tree is wasted. In by far the larger part of the State where this industry is carried on the supply of material (almost entirely white oak) is reported scarcer by 10 to 50 per cent.

The Carriage Builders' National Association last year had appointed a committee on timber supply. The chairman of the committee, Mr. H. G. Shepard, of New Haven, Conn., requested the co-operation of the division in ascertaining the present condition of supplies for this branch of wood-consuming industries, which is estimated to use annually about 25,000,000 cubic feet of wood of special quality, worth round $10,000,000. To gratify this reasonable demand, Mr. Adolph Leue, secretary of the Ohio Forestry Association, who had given some attention to the wagon and carriage manufacturers' interests, was asked to prepare himself for conducting such a canvass as would yield the desired information; but it was found that the finances of the division would not permit the undertaking of this canvass, and it had to be deferred.

The investigations into the technology of our timbers, and especially into the conditions upon which the qualities of our timbers depend—for which Mr. Roth, of Ann Arbor, had begun preliminary studies—has also made but slow progress for lack of means to supply proper material. As has been pointed out before, to make such investigations of practical utility the material for study must be very carefully collected by competent men, as it is necessary to note the conditions under which the samples have developed, and to make

certain determinations on the spot. Inability to command such competent assistance has put a check to Mr. Roth's work. He has furnished, however, a comparative study of the woods of the three prominent Southern pines—the Long-leaf, Short-leaf, and Loblolly, which will be printed eventually, together with the monographs on the life history of these trees.

These biological studies have been enriched during the year by several monographs on the most important Eastern pines, notably those of Dr. Charles Mohr on the Short-leaf, Loblolly, and Cuban pines. This last valuable pine, as yet but little known and not widely distributed, the observant author considers, for various reasons, as destined to replace the Long-leaf pine in the Southern forest of the future.

The monographs now on hand still unpublished comprise the following species: The White Pine (*Pinus Strobus*), by Prof. S. V. Spalding; the Norway and Pitch Pines (*Pinus resinosa and rigida*), by Prof. William Flint; the Hemlock (*Tsuga Canadensis*), by Prof. A. N. Prentiss; the two Northwestern spruces (*Picea nigra* and *alba*), by Miss Kate Furbish; the Long-leaf, Short-leaf, Loblolly, and Cuban pines (*Pinus palustris, mitis, Tæda* and *Cubensis*), by Dr. Charles Mohr.

The publication of these monographs, which give a complete account of the history and development of these trees, it is hoped will be no longer delayed, as they constitute the most valuable work in the division within the last three years. The illustrations which are to accompany these—woodcuts of the highest order—have been partly finished during the year, and will enhance the value of the publication.

During the first months of the year much time was spent in finishing the collective forestry exhibit for the Paris Exposition, which was accompanied by a report—so far published only in French—giving a bird's-eye view of forests, forest conditions, and forest utilization in the United States.

The exhibit, which attempted in a small compass to give a systematic view of these matters, was recognized by the grant of a gold medal. Another gold medal was bestowed upon the writer for his efforts in forest educational direction, and several of the exhibitors in the section of forestry received prizes. A model of a tree-planting machine, described in my last year's report, was also recognized by a gold medal, and a bronze medal was accorded for a collection of forest-tree seeds.

In this connection it may be of interest to mention that the authorities of the National Museum have seen fit to establish a special branch of forestry collections, which has been placed under the honorary curatorship of the writer. It is a promising sign for the cause of forestry in this country that such recognition has been given to its existence and importance, since the idea of establishing such special collections is original and not copied from any of the other national museums of the world. For the present, therefore, the educational value of this departure will be mainly kept in view in these exhibits.

During the summer the writer furnished an extensive report for the use of the Senate Committee on Irrigation, outlining the relation of forests to irrigation problems. For the better performance of this task, an extended but rapid journey across the regions under consideration was made by the writer, which afforded a bird's-eye

view of the varying conditions prevailing over the treeless plains and wooded plateaus and mountains of the west. A short side trip into the Puget Sound regions, the red woods of California, and into the Sierra Nevada was crowded into the journey, to gain a long-needed personal insight into the forest growths of those regions. Such a hasty journey, covering over 10,000 miles of travel in less than seven weeks, can of course lead to nothing more than impressions and the gathering of a few unconnected notes of interest. Some of these may be pertinent enough to be here briefly stated:

(1) The dryness of the plains east of the Rocky Mountains, as far as it is inimical to vegetation, is due, probably, not so much to the small rain-fall as to the enormous evaporation under the influence of the constant winds, which produce summer droughts as well as winter droughts. At least, the only means for influencing water conditions of a very large part of this region appears to be in checking or reducing this evaporation by the planting of wind-breaks and timber belts.

(2) The area which needs such protecting timber belts is so enormous that it seems almost hopeless to rely upon the effort of pioneer settlers for this work of timber planting, especially as the unsystematic manner in which such private planting must necessarily proceed, in addition to the existing most unfavorable climatic conditions, has led and must lead to failures more frequently than to successes.

(3) A tree will die where a forest would live; that is to say, planting on a large scale and in compact bodies may be successful, where smaller plantations will succumb to the extremes of the climate. Hence the poor settler on the frontier who can not afford to start a large enough plantation, will be doomed to reiterated failure and discouragement with his trees as well as his crops.

(4) The most serviceable trees for wind-breaks and for subsistence in a dry climate—the evergreen conifers—which require from six to ten times less water than most deciduous trees, do not recommend themselves to the use of pioneer planters, because they require much care to establish them in the open sites of the plains and grow only slowly to useful sizes.

(5) All these considerations lead to the conclusion that successful reclamation of these broad acres and effectual checking of the destructive winds by means of systematic planting of forest belts can only be attained by co-operation, *i. e.*, by government management, be it national, State, or county.

(6) The most promising conifers for planting on the plains and prairies, besides the Scotch, Austrian, and Norway Pines and the Juniper or Red Cedar in the lower latitudes, seem to be the two Rocky Mountain conifers, the Bull Pine and the Douglas Spruce.

(7) The condition of the Western mountain forests, upon which largely the water supply for irrigation purposes depends, is most discouraging, and the result of their devastation is already noticeable in the irrigation works around Greeley, Denver, and in other localities. During this summer hundreds of square miles have been destroyed by fire — not simply burnt over but destroyed. The irrational treatment which this valuable property, still in the hands of the General Government, receives has been pointed out *ad nauseam*. The people in the San Joaquin Valley have at last begun to realize the influence of the wooded mountain crests upon their supply of water for irrigation, and have, in mass meetings, demanded the reservation and administration of these forest lands. The difficulty of devising

a proper system of protection and management, it is believed, is entirely overstated and with good will could no doubt be overcome.

(8) In the protection of these timber areas the judicious and systematic use of fire—burning over protective belts during the season of least danger—will reduce the need of forest guards.

(9) The reproduction of the coniferous woods of the West is in many localities not as readily accomplished as is desirable, the forest-floor having been destroyed by recurring fires, conditions for germination have been destroyed also. Large areas in the Colorado Mountains were seen without a sign of young growth. The red woods of California are doomed, it seems, to absolute extinction, for reproduction by seed is hardly noticeable, and the vigorous reproduction from the stump, in which this conifer excels all others (the ephemeral sprouts of *Pinus rigida* and *mitis* are of no account), seems not to find satisfactory conditions for development.

(10) During this trip the plantations made by the tree-planting machine, described in my last report, were visited and found to be superior to any others in the same locality (Stratton, Nebr.). They consisted largely of Russian mulberry planted three years, which for rapid soil-cover and hardiness seems a most commendable plant in that droughty region.

The policy of giving to the Chief of the Forestry Division an occasional opportunity to see a forest and to inspect the conditions of the country for which he is called upon to devise means of improvement may be considered not an unwise one. The more directly in touch he can be with the people and their wants the more practical will become his direction of the work. The objection to "book-learning" which is so often heard can only be overcome by giving liberal opportunity for personal observation.

During the year the office facilities have been somewhat increased. The herbarium, which was fortunately sufficiently advanced to furnish needed material upon the sudden call for an exhibit at the Paris Exposition, has been enlarged, as also the seed collection; so that soon these first requisites for a student of forest botany will be on hand. The library, too, has been further enlarged, and now the Forestry Division is perhaps the best equipped place in this country for students of forestry. This does not mean much, and room for improvement even in this direction is ample.

Besides Bulletin 3, on The Use of Metal Track on Railways, a second edition of Bulletin 2, on The Forest Conditions of the Rocky Mountains, became necessary and was printed. A circular on Arbor Day Planting, describing the proper methods of planting trees and giving advice on the selection of proper kinds, was issued early in the year.

SEED AND SEEDLING DISTRIBUTION.

In my former reports I have pointed out the perplexities which are experienced in trying to satisfy the requirement expressed in the appropriation for the division, "to collect and distribute valuable economic tree-seeds and plants." I have shown that, unlike most agricultural seeds, tree-seeds, as a rule, do not permit of long storage and in order not to lose their power of germination must be more carefully handled and more rapidly disposed of than the facilities of the Department permit; many desirable kinds, in fact, allow no handling at all but must be sown as soon as ripe. I have further shown that few people know how to handle tree-seeds in the seed-

bed, except the commonest and most easily grown kinds; that the length of time before a plantlet fit for transplanting is obtained will almost invariably weary the patience of the average settler; that distribution of plants while more cumbersome and costly is more likely to insure success, but that such distribution must be done under a well prepared plan, such as I have indicated in my report for 1887. The choice of plants instead of seeds is especially preferable for the droughty localities of the Western plains.

From the small amounts appropriated for the work of the division only insignificant sums can be spared for the purchase of seeds and seedlings; in fact, during the preceding year no purchases could be made, and therefore no distribution was made during this season. But a report was called for from those who had received seeds and seedlings the year before. These reports are most discouraging. A short synopsis of the reported results is herewith given, with some notes which show that nevertheless some desirable experience has been derived from these trials.

Report on tree-seed and seedling distribution, 1887–'88, *Forestry Division.*

NOTE.—The seedlings were sent out in packages of twenty-five each, with the exception of *Prunus serotina* (Black Cherry), of which only five were sent in a package. The column of "Total failures" indicates the number of reports showing entire want of success. To each applicant two or four packages of seed were usually sent, sometimes only one. The possibilities of success are indicated by marking in the column of "Best reports," the number of packages used in obtaining the specified number of seedlings.

DAKOTA.

Names of species.	Number of seedling reports.	Number of plants sent.	Per cent. living.	Total failures.	Number reporting success.	Per cent. of success.	Best report per cent.	Number of seed reports.	Packages of seed sent.	Seedlings from seed.	Best report number.
Pinus sylvestris (Scotch Pine)	23	575	7	18	5	32	*a*80	0	0	......	......
Pinus Austriaca (Austrian Pine)	23	575	5.22	17	6	20	*a*48	0	0	......	......
Pinus Strobus (White Pine)	16	400	5.25	13	3	28	*a*40	11	24	0	......
Pinus resinosa (Red Pine)	0	0	......	...	....	......	......	13	25	0	......
Pinus mitis (Short-leaved Pine)	0	0	......	...	....	......	......	0	0	......	......
Pinus ponderosa (Bull Pine)	0	0	......	...	....	......	......	5	6	0	......
Pinus laricio (Corsican Pine)	10	250	11.6	6	4	29	*a*40	10	20	0	......
Picea excelsa (Norway Spruce)	20	500	8.8	14	6	29.33	*a*80	0	0	....	......
Pseudotsuga Douglasii (Douglas Spruce)	9	225	0.9	8	1	8	8	9	16	300	1pk 300
Libocedrus decurrens (California White Cedar)	0	0	......	...	....	......	......	1	0	......	......
Juniperus Virginiana (Red Cedar)	0	0	......	...	....	......	......	10	22	0	......
Taxodium distichum (Bald Cypress)	0	0	......	...	....	......	......	0	0	......	......
Larix Europæa (European Larch)	19	475	9.47	13	6	30	*a*60	0	0	....	......
Fraxinus Americana (White Ash)	5	125	60	1	4	75	*b c*80	0	0	......	......
Fraxinus viridis (Green Ash)	7	175	44.6	2	5	62.4	*b c*80	15	31	325	2pks 100
Prunus serotina (Black Cherry)	5	25	48	2	3	16	*c*80	0	0	......	......
Gleditschia triacanthos (Honey Locust)	1	4	0	1	....	......	......	5	14	24	1pk 24
Robinia pseudacacia (Black Locust)	1	25	0	1	....	......	......	16	41	130	1pk 130
Catalpa speciosa (Hardy Catalpa)	3	75	25.3	0	3	25.33	*d*48	11	22	8	2pks 8
Acer dasycarpum (Silver-leaved Maple)	6	150	40	2	4	40	*b*80	0	0	.....	......
Negundo aceroides (Box-Elder)	6	150	60.7	1	5	72.8	*b c*80	13	29	270	2pks 200
Maclura aurantiaca (Osage Orange)	1	4	0	1	....	......	......	1	4	0	......
Total	155	3,733	14.62	100	55	35.9	62	120	254	1,049	1pk 300

Report on tree-seed and seedling distribution, etc.—Continued.

NEBRASKA.

Names of species.	Number of seedling reports.	Number of plants sent.	Per cent. living.	Total failures.	Number reporting success.	Per cent. of success.	Best report per cent.	Number of seed reports.	Packages of seed sent.	Seedlings from seed.	Best report number.
Pinus sylvestris (Scotch Pine)	13	350	14	6	7	28	*e*80	0	0	......	......
Pinus Austriaca (Austrian Pine)	13	350	9.1	7	6	21.33	*i*32	0	0	......	......
Pinus Strobus (White Pine)	1	25	0	1	....	......	......	1	4	0	......
Pinus resinosa (Red Pine)	0	0	......	....	....	......	......	2	3	0	......
Pinus mitis (Short-leaved Pine)	0	0	......	....	....	......	......	0	0	......	......
Pinus ponderosa (Bull Pine)	0	0	......	....	....	......	......	3	4	0	......
Pinus laricio (Corsican Pine)	0	0	......	....	....	......	......	1	2	0	......
Picea excelsa (Norway Spruce)	1	25	16	....	1	16	*h*16	0	0	......	......
Pseudotsuga Douglasii (Douglas Spruce)	9	225	24.4	5	4	55	*e f*84	2	3	0	......
Libocedrus decurrens (California White Cedar)	0	0	......	....	....	......	......	1	1	0	......
Juniperus Virginiana (Red Cedar)	0	0	......	....	....	......	......	2	8	0	......
Taxodium distichum (Bald Cypress)	0	0	......	....	....	......	......	0	0	......	......
Larix Europæa (European Larch)	1	25	0	1	....	......	......	....	....	......	......
Fraxinus Americana (White Ash)	0	0	......	....	....	......	......	0	0	......	......
Fraxinus viridis (Green Ash)	3	75	60	0	3	60	*g j*80	2	6	0	......
Prunus serotina (Black Cherry)	1	5	80	0	1	80	*g*80	....	....	......	......
Gleditschia triacanthos (Honey Locust)	1	25	20	0	1	20	*h*20	1	4	11	4pks 11
Robinia pseudacacia (Black Locust)	1	25	4	0	1	4	4	2	8	20	4pks 20
Catalpa speciosa (Hardy Catalpa)	11	275	62.9	1	10	55.64	*b g*100	1	2	400	2pks 400
Acer dasycarpum (Silver-leaved Maple)	1	25	24	0	1	24	*g*24	0	0	......	......
Negundo aceroides (Box-Elder)	1	25	80	0	1	80	*g*80	2	6	500	2pks 500
Maclura aurantiaca (Osage Orange)	0	0	......	....	....	......	......	1	4	0	......
Total	57	1,455	26.06	21	36	40.36	54.5	21	55	931	2pks 500

KANSAS.

Names of species.	Number of seedling reports.	Number of plants sent.	Per cent. living.	Total failures.	Number reporting success.	Per cent. of success.	Best report per cent.	Number of seed reports.	Packages of seed sent.	Seedlings from seed.	Best report number.
Pinus sylvestris (Scotch Pine)	29	725	3.4	17	12	8.33	*k*40	0	0	......	......
Pinus Austriaca (Austrian Pine)	28	700	0.57	25	3	5.3	*k*8	0	0	......	......
Pinus Strobus (White Pine)	5	125	0	5	....	......	......	6	24	0	......
Pinus resinosa (Red Pine)	0	0	......	....	....	......	......	6	12	0	......
Pinus mitis (Short-leaved Pine)	0	0	......	....	....	......	......	0	0		......
Pinus ponderosa (Bull Pine)	0	0	......	....	....	......	......	6	12	0	......
Pinus laricio (Corsican Pine)	5	125	0	5	....	......	......	4	8	0	......
Picea excelsa (Norway Spruce)	0	0	......	....	....	......	......	0	0	......	......
Pseudotsuga Douglasii (Douglas Spruce)	13	325	.61	11	2	4	*m*4	1	2	0	......
Libocedrus decurrens (California White Cedar)	0	0	......	....	....	......	......	6	6	0	......
Juniperus Virginiana (Red Cedar)	0	0	......	....	....	......	......	6	14	0	......
Taxodium distichum (Bald Cypress)	0	0	......	....	....	......	......	5	20	0	......
Larix Europæa (European Larch)	0	0	......	....	....	......	......	0	0	......	......
Fraxinus Americana (White Ash)	0	0	......	....	....	......	......	0	0	......	......
Fraxinus viridis (Green Ash)	4	100	21	0	4	21	*l n*32	7	13	302	2pks 300
Prunus serotina (Black Cherry)	1	5	0	1	....	......	......	0	0	......	......
Gleditschia triacanthos (Honey Locust)	5	125	44	1	4	55	*l*76	3	7	74	4pks 60
Robinia pseudacacia (Black Locust)	0	0	......	....	....	......	......	6	12	300	2pks 200
Catalpa speciosa (Hardy Catalpa)	24	600	50.5	5	19	62.1	*k l m n* 100	6	12	71	2pks 70
Acer dasycarpum (Silver-leaved Maple)	1	25	1	0	1	4	*l*4	2	3	0	......
Negundo aceroides (Box-Elder)	1	25	80	0	1	80	*l*80	7	13	450	1pk 250
Maclura aurantiaca (Osage Orange)	....	......	......	....	....	......	......	....	....	......	......
Total	116	2,880	14.76	70	46	29.83	43	71	155	1,197	1pk 250

Report on tree-seed and seedling distribution, etc.—Continued.

COLORADO.

Names of species.	Number of seedling reports.	Number of plants sent.	Per cent. living	Total failures.	Number reporting success.	Per cent. of success.	Best report per cent.	Number of seed reports.	Packages of seed sent.	Seedlings from seed.	Best report number.
Pinus sylvestris (Scotch Pine)	20	500	8.4	15	5	35.2	*o r s* 64	0	0	......	.....
Pinus Austriaca (Austrian Pine)	20	500	9.6	13	7	27.42	*o q* 48	0	0	......	.....
Pinus Strobus (White Pine)	1	25	0	1	....	....	....	0	0	......	......
Pinus resinosa (Red Pine)	0	0	....	....	....	....	....	13	26	800	2pks 800
Pinus mitis (Short-leaved Pine)	0	0	....	....	....	....	....	0	0	.....	......
Pinus ponderosa (Bull Pine)	0	0	....	....	....	....	....	12	23	300	2pks 300
Pinus laricio (Corsican Pine)	1	25	0	1	....	....	....	1	2	0	......
Picea excelsa (Norway Spruce)	0	0	....	....	....	....	....	0	0	......	......
Pseudotsuga Douglasii (Douglas Spruce)	14	350	5.7	12	2	4	*o* 72	0	0	......	......
Libocedrus decurrens (California White Cedar)	0	0	....	....	....	....	....	12	12	0	......
Juniperus Virginiana (Red Cedar)	0	0	....	....	....	....	....	13	28	0	......
Taxodium distichum (Bald Cypress)	0	0	....	....	....	....	....	2	8	0	......
Larix Europæa (European Larch)	0	0	....	....	....	....	....	0	0	......	......
Fraxinus Americana (White Ash)	0	0	....	....	....	....	....	1	1	37	1pk 37
Fraxinus viridis (Green Ash)	8	200	31	4	4	62	*p q* 100	14	28	2,100	2pks 2,000
Prunus serotina (Black Cherry)	1	5	20	0	1	20	*p* 20	0	0	......	......
Gleditschia triacanthos (Honey Locust)	13	325	29.8	6	7	55.43	*o r s* 100	1	4	0	......
Robinia pseudacacia (Black Locust)	0	0	....	....	....	....	....	12	26	1,512	2pks 1,500
Catalpa speciosa (Hardy Catalpa)	7	175	33.14	3	4	58	*p q* 100	14	51	845	2pks 800
Acer dasycarpum (Silver-leaved Maple)	0	0	....	....	....	....	....	.....	0	0	......
Negundo aceroides (Box-Elder)	1	25	100	0	1	100	*p* 100	12	24	1,615	2pks 1,500
Maclura aurantiaca (Osage Orange)	....	......	....	...	....	....	....	.....	....	....	......
Total	86	2,130	16.66	55	31	32.73	75.5	107	233	7,209	2pks 2,000

Localities of best reports: *a* New Salem. *b* Cavour and Sioux Falls. *c* Doland. *d* Glen Ullin. *e* Paxton and Newport. *f* Fleming. *g* Rushville. *h* Capay. *i* Newport. *j* Stratton. *k* Portland. *l* La Blanche. *m* Dermot. *n* Griswold. *o* Fort Collins. *p* Pueblo. *q* Rocky Ford. *r* Colorado Springs. *s* Hudson.

Only a limited number of reports have been returned and only those received from the four States appearing in the table did it seem worth while to tabulate.

Most of the reports, it should be stated, refer to hail or unusual drought during the last two seasons as producing the failures.

The column "best result" gives an indication of what individual success was possible. In fact the table shows most clearly that success, if we call success 40 per cent. saved through two years of unfavorable weather, was attainable in most cases by and is due to individual effort or knowledge. Thus of twenty-three reporting on Scotch pine in Nebraska, only five had any success ; but while these together saved forty plants (32 per cent. of what they received), one of them reports 80 per cent. or twenty plants living, leaving only twenty plants to the other four.

The same applies to success with seeds. Of nine applicants receiving sixteen packages of seed of Douglas Spruce only one was successful, raising three hundred plants from one package ; and so it will be found that in almost every case the success was with one man,

showing that failure could have been avoided and was not necessarily due to uncontrollable conditions.

The locality in which the best success (above 40 per cent.) with each species was obtained is denoted in foot notes.

Altogether, more total success is reported from Nebraska than from the other States, although individual success was greatest in Dakota. It may be noted, that of the conifers the Scotch Pine did best, and next to it the Douglas Spruce, with 84 per cent. in Nebraska and 72 in Colorado.

This tree also, together with the Red Pine and Bull Pine gave results, each in one case, from the seed. Of deciduous trees the Catalpa shows the most uniform success, except in Dakota, where it is perhaps out of its range.

There can be only three objects in the distribution of plant material which are worthy and desirable for the Department to attain: either to give aid to and stimulate by it the efforts of forest planters, to test the adaptability of certain kinds to certain localities, or to introduce new desirable species and facilitate the use of certain kinds which have not found favor for some reason outside of their intrinsic value—such as high price, difficulty of obtaining seed, slow growth, etc.

The first object can of course only be attained by giving sufficiently large quantities of plants of acknowledged value. How futile it would be on the part of the Department, with its present appropriations, to distribute plant material with this object in view, will appear readily from an inspection of the subjoined table, exhibiting the number and acreage of timber-culture entries. There are now on the average 25,000 claims entered annually. Even if the distribution were confined only to these planters and not more than the material for one acre were furnished—a small enough encouragement —the amount to be spent in that direction would have to be not less than $150,000.

If the introduction of untested kinds is the object, then, as the foregoing synopsis of reports may show, the distribution should go only to experienced planters, who can give proper attention and are able to judge whether failure is due to external causes which may be controlled, or to inherent qualities of the species tested. The third object, namely, to facilitate the introduction of kinds difficult to obtain, would tax the financial conditions of the division for only a small result. Yet this consideration is a proper one, and has somewhat directed the selection of the material which has been used for distribution. Thus seeds of two valuable *Acacias* were obtained from Australia, and seeds of *Abies Nordmanniana* from Asia Minor, the latter now recognized as by all means the best fir for ornament, timber, or hardiness. Of native trees, the Bald Cypress (*Taxodium distichum*), a tree of our Southern swamps, has proved better than was hoped for, namely, that it is drought-proof and a most rapid grower even on the uplands of Texas. The wild black cherry was also selected for distribution, as it promises to become one of the most promising trees for Western planting. The Bull Pine (*Pinus ponderosa*) and the Douglas Fir (*Pseudotsuga Douglasii*), the most prominent conifers of the Rocky Mountain region, which should have a full trial in the plains country, have been secured for distribution this season. It is objected, and quite properly, that conifer seeds are too difficult for the inexperienced planter to handle, and

that it would be preferable to send well-rooted plants. It is therefore proposed to send these seeds largely to Experiment Stations, through the medium of which the plants could be distributed when grown, in the same manner as is now done at the California Experiment Station, by charging enough to cover the cost of packing and postage. A small assortment of seeds of the various more commonly planted trees, in half-ounce and ounce packages, is also kept on hand to satisfy applications.

TIMBER-CULTURE ACT.

It seems proper for this division to keep a watchful eye on any movement that promises an increase of forest area and to note especially the working of the timber-culture act, as far as it promises to clothe the treeless plains with a forest cover. The following compilation of the status of timber-culture entries from the reports of the General Land Office one would be inclined to think would furnish, at least approximately, an idea of the area planted to timber; but since it may be said that the majority of these entries have not only changed hands, and thus appear in the annual statements repeatedly, but have also been changed to entries of other kinds, no conception of the actual area planted can be gained from the study of these figures. They do show, however, that even with these conditions, which tend to increase the figures, the results of the act are so far not satisfactory. An analysis of the figures shows that 38,080,506 acres were entered under the timber-culture act up to June 30, 1888. This should represent a planted area of 2,380,030 acres, if the law were complied with and the entries not changed. Allowing ten years for timber-claim planters to prove up their entries (the law places it at eight years, allowing extensions on account of failures), the entries of the first six years, 1873 to 1878, alone give us some points of comparison for the estimation of results. During that time 3,821,843 acres were proved up, representing an area of less than 50,000 acres planted to timber.

From this it would appear that the timber-culture act has been a failure, so far as the creating of forests is concerned.

It is asserted that a better percentage will be obtained from the entries of later years, because more experience has been gained, and timber-claim planting is now done under contract by persons who make a business of it. Yet the consensus of unbiased testimony goes to show that timber-claim planting, as a rule, does not produce the results sought after, and has mostly been used as a means for speculation in Government lands, partly with that design from the beginning, partly as a necessity after failure to obtain the land by timber planting.

There is also considerable planting of wind-breaks and groves done on homesteads, which is said to be attended with better results. Altogether, however, the amount of tree planting is infinitesimal, if compared with what is necessary for climatic amelioration; and it may be admitted, now as well as later, that the reforestation of the plains must be a matter of co-operative if not of national enterprise.

Original and final entries under the timber-culture act.

State or Territory.	1873—Original.		1874—Original.		1875—Original.		1876—Original.		1877—Original.	
	No.	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*
Arizona	......	....	2	196	2	320	10	1,197	21	2,440
Arkansas	......	....	......	....	......	....	3	231	......	....
California	2	329	59	8,878	195	29,065	136	20,524	75	10,586
Colorado	......	....	17	2,272	27	3,453	45	6,514	28	3,343
Dakota	24	3,560	865	124,997	451	61,969	842	119,835	476	68,266
Idaho	......	....	2	180	21	2,583	17	1,973	52	7,035
Iowa	1	145	33	3,816	92	9,127	99	8,563	59	4,791
Kansas	60	9,642	1,954	282,479	1,265	168,269	1,354	185,596	1,666	238,020
Louisiana	......	....	......	....	......	....	......	....	......	....
Minnesota	95	14,710	804	113,131	499	63,673	1,070	140,126	561	76,021
Montana	......	....	......	....	......	....	......	....	3	398
Nebraska	137	21,858	2,264	312,712	1,061	130,894	834	106,499	706	90,812
Nevada	......	....	......	....	......	....	......	....	2	240
New Mexico	......	....	......	....	......	....	7	1,128	......	....
Oregon	......	....	......	....	7	882	13	1,793	19	2,509
Utah	......	....	......	....	......	....	3	399	3	338
Washington	......	....	22	2,482	31	3,324	54	5,374	148	19,746
Wyoming	......	....	1	80	1	130	1	160	......	....
Total	319	50,244	5,923	851,223	3,652	473,689	4,488	599,912	3,819	524,545

State or Territory.	1878—Original.		1879—Original.		1880—Original.		1881—Original.	
	No.	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*
Arizona	11	1,600	21	3,280	6	719	6	760
Arkansas	......	....	......	....	......	....	......	....
California	60	8,029	112	14,458	99	12,120	201	24,538
Colorado	125	17,436	121	16,142	214	30,302	195	26,473
Dakota	......	....	4,675	728,687	5,575	868,748	5,133	868,400
Idaho	158	22,169	162	22,013	181	23,300	224	28,680
Iowa	89	7,535	73	6,577	57	4,714	55	3,643
Kansas	4,031	593,295	7,776	1,167,582	2,891	408,261	1,924	268,575
Louisiana	......	....	1	80	1	40	19	2,293
Minnesota	2,693	377,017	1,847	257,642	909	123,735	1,168	167,582
Montana	9	960	27	3,134	61	6,835	131	16,535
Nebraska	1,408	195,306	3,183	465,968	3,202	475,275	1,682	240,306
Nevada	5	600	1	160	5	560	7	1,040
New Mexico	2	320	14	1,891	24	2,887	16	2,039
Oregon	130	18,446	117	17,046	482	73,061	212	31,176
Utah	9	1,280	20	2,328	35	4,044	35	3,921
Washington	562	78,237	479	68,506	893	134,637	540	77,008
Wyoming	......	....	......	....	9	240	5	784
Total	9,292	1,322,230	18,629	2,775,494	14,644	2,168,478	11,553	1,763,754

State or Territory.	1882.				1883.				1884.			
	Original.		Final.		Original.		Final.		Original.		Final.	
	No.	*Acres.*	*No.*	*Acres*	*No.*	*Acres.*	*No.*	*Acres*	*No.*	*Acres.*	*No.*	*Acres*
Arizona	9	1,352	....	......	33	4,336	....	......	41	5,483	....	......
Arkansas	......	....	....	......	......	....	....	......	1	80	....	......
California	306	39,88	....	......	327	44,670	1	160	535	72,319	1	160
Colorado	329	47,436	....	......	413	58,685	....	......	917	137,933	1	160
Dakota	9,368	1,446,532	4	521	1,199	1,755,419	111	14,968	11 279	1,748,640	166	21,470
Idaho	272	33,[illegible]65	....	......	310	40,105	....	......	407	56,171	1	180
Iowa	82	6,235	....	......	42	3,373	20	2,165	45	3,346	27	2,794
Kansas	1,933	273.053	71	9,915	1,690	237,860	185	24,965	2,738	397,525	181	23,093
Louisiana	[illegible]	1,004	....	......	52	7,754	....	......	265	38,788	....	......
Minnesota	1,220	176,741	21	2,998	883	122,750	84	11,495	689	95,538	90	12,324
Montana	266	35,409	....	......	403	53,952	....	......	471	63,283	....	......
Nebraska	2,806	298,520	68	9,975	3,216	481,704	317	43,522	2,933	1,068,189	239	30,040
Nevada	10	1,520	....	......	2	280	....	......	1	159	....	......
New Mexico	24	3,351	....	......	159	22,091	....	......	131	17,945	....	......
Oregon	590	88,038	....	......	767	116,334	2	240	978	148,356	1	160
Utah	32	3,831	....	......	62	7,509	....	......	86	11,192	....	......
Washington	603	87,[illegible]24	....	......	944	139,737	3	320	1,158	173,142	7	914
Wyoming	20	2,284	....	......	98	14,204	....	......	321	46 027	....	......
Total	17,877	2,546,677	164	23,409	10,600	3,111,763	723	97,835	22,996	4,084,116	714	91,295

Original and final entries under the timber-culture act—Continued.

State or Territory.	1885.				1886.			
	Original.		Final.		Original.		Final.	
	No.	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*
Arizona	134	19,542	1	160	113	15,772	1	160
Arkansas	4	640	......	....	19	2,025	......	....
California	592	9,406	3	480	1,136	155,674	......	....
Colorado	1,356	20,498	2	240	4,598	719,947	4	559
Dakota	8,499	1,328,966	161	21,207	7,030	1,098,958	275	39,591
Idaho	372	48,255	......	....	386	49,959	2	240
Iowa	63	3,647	17	1,437	44	2,869	13	1,014
Kansas	7,557	1,169,303	214	27,133	12,193	1,920,802	315	42,657
Louisiana	110	15,598	......	....	72	9,914	......	....
Minnesota	604	79,410	109	13,618	507	65,026	174	24,311
Montana	304	41,207	......	....	324	43,031	1	160
Nebraska	9,436	1,468,114	190	25,037	6,234	969,706	215	28,278
Nevada	......	....	......	....	1	120	......	....
New Mexico	125	16,286	......	....	123	15,603	......	....
Oregon	664	97,331	1	160	651	93,160	6	880
Utah	127	15,842	1	80	200	25,632	......	....
Washington	561	81,851	51	1,017	597	85,645	30	3,920
Wyoming	460	67,243	......	....	663	100,167	......	....
Total	30,968	4,483,139	750	90,569	34,891	5,374,010	1,036	141,770

State or Territory.	1887.				1888.			
	Original.		Final.		Original.		Final.	
	No.	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*	*No.*	*Acres.*
Arizona	144	20,199	2	320	303	45,374	......	....
Arkansas	7	840	......	....	5	600	......	....
California	1,168	165,382	1	40	1,668	240,216	1	49
Colorado	9,092	1,437,636	4	559	6,173	970,281	7	760
Dakota	4,194	650,420	387	57,311	4,037	626,629	202	29,996
Idaho	306	38,912	3	400	387	51,717	9	891
Iowa	60	4,945	15	1,207	37	2,187	32	2,888
Kansas	4,405	686,137	157	21,881	4,746	732,545	421	56,502
Louisiana	65	9,402	......	....	80	11,469	......	....
Minnesota	395	52,306	185	25,009	433	56,622	118	15,003
Montana	282	38,847	2	280	274	36,407	1	39
Nebraska	5,310	794,047	379	52,541	4,277	660,915	345	48,264
Nevada	4	640	......	....	4	560	......	....
New Mexico	168	23,695	......	....	266	39,692	3	326
Oregon	643	93,137	8	920	855	126,979	29	4,436
Utah	179	21,638	1	160	257	30,234	4	420
Washington	482	67,568	54	7,686	599	89,980	49	6,816
Wyoming	462	69,814	......	....	360	53,260	......	....
Total	27,366	4,175,565	1,198	168,314	24,761	3,775,667	1,221	166,390

SUMMARY.

State or Territory.	Original entries.		Final entries.	
	No.	*Acres.*	*No.*	*Acres.*
Arizona	856	122,570	4	640
Arkansas	39	4,416	......	....
California	6,671	856,076	7	889
Colorado	23,650	3,498,351	18	2,278
Dakota	63,647	11,500,026	1,306	185,064
Idaho	3,257	427,017	15	1,711
Iowa	931	75,514	124	11,505
Kansas	58,183	8,738,944	1,544	206,146
Louisiana	672	96,342	......	....
Minnesota	14,377	1,882,030	781	104,758
Montana	2,555	339,998	4	479
Nebraska	48,589	7,780,825	1,753	237,657
Nevada	42	5,879	......	....
New Mexico	1,059	146,928	3	326
Oregon	6,128	908,248	47	6,796
Utah	1,048	128,188	6	660
Washington	7,673	1,114,761	194	20,673
Wyoming	2,401	454,393	......	....
Total	241,778	38,080,506	5,806	779,582

OSIER CULTURE.

In my report for 1886 there was given a brief instruction for osier-growing and a fuller manual was promised. The manuscript of this manual has remained unfinished and unpublished for want of sufficient knowledge to write the chapter on the selection of kinds to be grown. This knowledge can only be obtained by actual experiment, for which, at the time and since, the Department did not have the means or facilities. By private endeavor of the writer, and through the favor of a prominent osier-grower in Austria, Heinrich Ritter von Manner, a selection of rods of some seventy varieties was obtained in the spring of 1887, and cuttings were distributed to the various experiment stations.

The long journey, absence of facilities to readily prepare and send the cuttings from here, and the consequent delay in reaching their destination proved detrimental to a large number, and in most cases the experiment stations which have been heard from report entire failure. Yet the reports from the Agricultural College, Michigan; State College, Pennsylvania, and the Agricultural Experiment Stations at Berkeley, Cal., indicate that these stations have been able to save quite a number. Mr. Sudworth, of this division, secured space in some private grounds and planted the full selection, with the results as stated in table below.

The report of Professor Hilgard, of California, is specially satisfactory, as he has been able to grow nine varieties in sufficient quantities to announce a distribution of plant material in lots of ten cuttings of a kind for 10 cents or 1 dozen assorted at 20 cents. He does not, however, propose to extend this distribution beyond the limits of his State.

These experiments, although giving no definite answer as yet either in regard to adaptability to our climate or the basket-making properties of these varieties when grown under our hot sun, have yet given an indication that the repetition of this introduction would be a proper course for the Department. It should be added that the plants (except probably those in California) were not cut down as they should have been after the first season. The largest number were saved at State College, Pennsylvania. Professor Buckhout reports fifty-nine alive, although more than half in poor condition, and says:

> The cuttings came wrapped in oiled paper and in good condition; they were put out in rows 6 inches apart in the row, and have received ordinary cultivation and light hoeing, such as is usually given to nursery stock; soil, rather heavy clay loam with flint gravel; high uplands.

The Roman numbers in the table refer to varieties which are more commonly used in Europe.

Results of growing

Register number.	Name.	Pennsylvania.	
		Height.	Remarks on growth.*
		Ft. in.	
I	Salix amygdalina canescens	1 6	Poor growth
III	Salix amygdalina latifolia	1 3	......do
57	Salix amygdalina palida	2	Stout (one-half inch) and fairly vigorous
59	Salix amygdalina spadicea	6	Very poor growth
60	Salix amygdalina regalis	6	......do
61	Salix amygdalina lutea	6	......do
66	Salix amygdalina inflexa	1 3	Poor growth
67	Salix amygdalina italica nigra	1	......do
69	Salix amygdalina erecta	....	
70	Salix amygdalina crispifolia	1 6	Fair growth
71	Salix amygdalina picta	1 3	......do
72	Salix amygdalina italica alba	1	Poor growth
114	Salix amygdalina pyrifolia	2 6	Good growth and tough
139	Salix amygdalina supera	....	
81	Salix alba flora	2 6	Good growth and tough (yellow bark)
83	Salix alba vitellina	2 6	......do
87	Salix alba casteriana	1	Poor growth
112	Salix hastata	2 6	Good growth and tough (yellow orange).
21	Salix fragilis	2	Good growth
22	Salix fragilis pentandra	2	......do
37	Salix purpurea	5	Good growth, slender, tough
XXI	Salix purpurea (Stone Willow)	....	
38	Salix purpurea (wild, from Danube)	....	
24	Salix purpurea pyramidalis	3	Good growth
29	Salix purpurea Kerksii	3	......do
30	Salix purpurea gracilis	3	......do
IV	Salix purpurea × viminalis	1	Poor growth
25	Salix Helix	2	Good growth
131	Salix uralensis (from Galicia)	4	Good growth, slender, tough (red-gray).
35	Salix uralensis serotina	1 6	Poor growth
44	Salix rubra viridis	1 3	......do
116	Salix rubra cinnamomea	2 6	Good growth and tough
X	Salix viminalis (Belgian)	....	
XI	Salix viminalis (Rough Golden)	1 6	Fair growth
XII	Salix viminalis (Rough Red)	1 6	......do
XIII	Salix viminalis (Smooth Golden)	2	......do
XIV	Salix viminalis (Rough Green)	2 6	......do
XV	Salix viminalis (high-growing varieties)	....	
143	Salix viminalis (French)	1	Poor growth
144	Salix viminalis (English Longskin)	1 3	......do
6	Salix viminalis alba	1	Very poor growth
9	Salix viminalis stricta	1 6	Fair growth
14	Salix viminalis meliorata	....	
16	Salix viminalis patula	6	Very poor growth
142	Salix viminalis nobilis	....	
XXX	Salix hippophaëfolia	1 6	Fair growth

* Cuttings arrived in good condition. Set in rows 6 inches apart in the row, and receiving ordinary cultivation and light hoeing. Soil rather heavy clay loam with flint gravel; high upland, with no extra moisture or periodic overflow.

varieties of Osiers.

Washington, D. C.		California.	Michigan.	
Height.	Remarks on growth.†	Remarks on growth.	Height.	Remarks on growth.
Ft. in.			*Ft in.*	
8	Very stout (one-half to one inch) much branched, bush-like.			
1 6	Slender, producing clean rods	Rather small rods; wood hard (dark green bark).		
3 10	Slightly branched, but tending to produce good rods.			
8 6	Producing clean slender rods			
3 6	Slightly branched, but mostly good rods.			
3 6	do		1	
6	do			
7	do			
3 8	do			
3 6	do			
7 6	Producing clean slender rods			
4	do			
4 8	do			
4 6	do			
			4 6	
9	Producing clean slender rods			
3	Slightly branched, but mostly good rods.			
5 9	do			
6 6	Producing clean slender rods		4	Soil usually moist, but dry in 1889. Well cultivated and hoed. Some plants set too near other small trees. A number of other species are still alive, but with growth of less than one foot.
7	do			
1 6	Stunted and branched; suffered from drought.		1	
7 6	Slightly branched, but mostly good rods.		2	
		Strong grower (bark greenish yellow).	2	
			2 6	
			4	
		Rather small, slim growth (bark greenish yellow).		
3	Slightly branched, but mostly good rods.		3	
		Long rods (bark greenish yellow).		
3 6	Slightly branched, but mostly good rods.			
3 10	do		2 6	
3 6	do			
2 10	do			
		Medium grower (bark greenish yellow).		
5	Producing clean slender rods			
		Strong grower (bark greenish yellow).		
5 3	Slightly branched, but mostly good rods.	Strong grower (reddish bark).		

† Cuttings placed in water 36 hours before planting. Soil rather sandy clay loam; upland moderately rich. Situation, north side of 9-foot tight board fence. Ground roughly spaded; cuttings set in row 6 inches apart. No care was given the cuttings after planting, except pulling of rank weeds tending to choke the willows, and cutting of grass and weeds on either side of row once during the season.

It is to be understood that of the numberless varieties of willows, not all are Osier Willows fit for basket-work; and again, of those which grow rods fit for such work, there are some adapted to coarse work only, while others can be used in the finer ware. The fine ware is at present almost entirely imported, the reason being partly the absence of proper material grown in this country and partly, probably, labor conditions.

The native willows are locally used for basket-work of indifferent quality, but it is not known at this office that they are grown for profit, and they have not been but ought to be tested as to their qualities for profitable Osier growing.

The requirements for a good Osier Willow are, that it produce many slender rods without branching, that the rods be soft and pliable, that the rods when peeled be of white color preferably, that the stocks will re-produce for a long time and vigorously.

Of the European kinds, the *Salix purpurea* (Red Osier) is mostly grown in this country, but evidently under the climatic conditions of some parts of our country it does not thrive as well as in Europe. The hot sun and the cold winters seem specially to influence the hardness of the rod, reducing the pith to a minimum, while the desirable rod must be soft, pliable, and have a large pith, and when peeled show along the rod only small closed eyes; the open elongated eyes being a sign of weakness. In new introductions, especially into the Southern and Middle States, the softest kinds should be looked to first, as they will harden anyhow.

The letters asking for advice in Osier culture and inquiries as to its profitableness are becoming more and more frequent, probably because it is believed to be a simple and easy means of starting a very profitable business. I have seen no reason to change my opinion, expressed in the report for 1886, that it is mainly a ready market and labor conditions which make Osier growing profitable in some localities, such as Syracuse, St. Louis, Cincinnati, Chicago, around New York, etc.

The salt manufacture around Syracuse, for instance, employs a large number of hands during the summer who would be out of employment during the winter if they had not basket-making to fall back upon; only few basket-makers work all the year round at their trade.

A few figures regarding the profit of Osier growing, obtained from the neighborhood of Syracuse, may be of interest. It is estimated that 5,000 people are more or less engaged in the business in that region, and the manufacture amounts to about 28,000 dozen baskets. One man will make eight baskets per day; three sizes of clothes baskets—hardly any other—are made, and the price for making is from \$1.70 to \$1.80 per dozen. The average quantity of rods needed per dozen of the smaller baskets is 20 pounds, a little more for larger.

The total cost for basket-making may be figured as follows:

Cost of 1 ton of green rods	\$15.00
Steaming and hauling to and from steam-box	2.25
Stripping	8.00
Making into baskets (14 dozen)	26.25
Cost of 14 dozen	51.50
Cost per dozen	3.67

As to the yield of the osier-holts around Syracuse, 4 tons of green rods per acre is an average crop, 6 tons a very good yield, and 8 tons have been occasionally obtained. The price per ton, green, has fallen from \$20 to \$15, while dry rods stripped will bring \$60 per ton. For steaming \$1 to \$1.50 per ton is paid, and for stripping \$6 to \$8; 2 to 2½ tons, green, yielding one ton of dry rods. Most of the rods are steam-peeled, which causes them to lose their whiteness and makes them less valuable; the steam is applied in boxes containing half a ton, in which the rods are steamed for ten hours. Sap-peeled rods are superior, in color at least, but require more care; they are cut in winter and kept in water for three weeks, when they may be peeled easily.

As to the methods of growing, I may refer to the report for 1886. In brief, the following points for establishing a good osier-holt may be repeated. A fresh soil, but by no means a wet one, thoroughly prepared to at least 16-inch depth by ditching and bringing the top soil to the bottom. Planting 12-inch long cuttings in early spring, making the rows 24 inches apart, the cuttings 4 inches in the row, which requires in round figures 65,000 cuttings per acre, costing about \$5 per thousand. Shallow cultivation to keep down weeds is required several times during the year; surface manuring is desirable. Cutting the rods down during the winter as close as possible to the ground with a smooth cut is desirable even after the first season, in order to get long, thin, and branchless rods the next year. A well-kept holt will increase in yield the first three years, then gradually decline, until it becomes unprofitable and must be newly planted after fifteen or sixteen years.

FORESTRY INTERESTS IN THE UNITED STATES.

Limited space permits only brief mention of the most notable events in the progress of forestry reform through the country during the last year.

Early in the year and soon after its annual meeting at Atlanta, Ga., a committee of the American Forestry Congress waited upon President Harrison and presented a memorial urging the adoption of an efficient Government policy for the preservation and protection of the public forests, and expressing the hope that the President would call the attention of Congress to the subject with a favorable recommendation of the action which was desired by the Forestry Congress.

At the meeting of the Forestry Congress (now having changed its name to that of the Forestry Association) at Philadelphia, in October last, a petition to Congress was adopted, urging the passage of an act withdrawing from sale all forest lands belonging to the nation, and committing them to the custody of the Army, until a commission shall have determined what regions should be kept permanently in forest and shall have presented a plan for a national forest administration. The appointment of such a commission through the President and necessary appropriations were also asked for.

The desirability of having a course of instruction in forestry at the agricultural colleges and of forestry experiments at every experiment station formed the subject of another resolution.

It deserves to be noticed also that the American Association for the Advancement of Science, at its meeting in August, at Toronto,

appointed a committee to represent the forestry interests of the nation to Congress.

Pursuant to the action of the Forestry Association, a forcibly written memorial has been addressed to the United States Congress, asking that the public lands in the arid regions of the West be withdrawn from sale, until it can be determined what portion of them are situated within the natural water-sheds of streams; that these be placed in the custody of the Department of Agriculture, the timber only thenceforth to be sold and the land kept as a permanent forest reserve.

A similar memorial has recently been presented to Congress by a committee appointed at a convention of the citizens of Fresno, Tulare, Kern, and Merced Counties, of California, asking for the permanent protection of the forests lying upon the water-sheds of those counties.

A memorial prepared by the State Board of Forestry of California presents the same requests in a broader application.

A movement has also been made in Colorado for the establishment of a public park in that State, a principal object of the movement being the preservation of the forests of a region which is the source of several large streams.

The fourth annual report of the Ohio Forestry Bureau shows a gratifying progress in advancing the interests of forestry in that State.

In Pennsylvania, although the Forestry Association failed to secure from the legislature the establishment of a permanent Forest Commission, they were successful in obtaining the repeal of the fence law, which had been upon the statute-book ever since the year 1700; a law which left the forests of the State largely exposed to the intrusion of cattle and their consequent injury. The repeal of the law will be of great advantage to the forests which remain.

In New York the report of the Forest Commission for 1888 indicates the need of a change in the laws in regard to the redemption of the land and the cancellation of the titles, in order to prevent the loss by the State of much land, valuable as a part of the forest reserve, which recent enactments have been designed to secure. The commission also asks that the further extension of railroads in the counties embraced within the forest reserve shall not be allowed, as such extension can not be regarded otherwise than as a calamity. They also ask for such an appropriation from the State treasury as will enable them to purchase, for the purpose of increasing the forest domain, such forest lands as can be bought at a fair valuation.

In New Hampshire, the last legislature established a commission "to examine and ascertain the feasibility of the purchase by the State of the whole or any portion of the timber lands upon the hills or mountains of the State, near summer resorts, or bordering upon the principal sources of the water supplies needed for manufacturing purposes, with a view of preserving the same as public lands and parks." The commission is organized and actively at work.

In Massachusetts a notable forestry movement has been made by the town of Lynn. At the first settlement of the State Lynn, the second town established in it, had a wild piece of woodland which was held in common until 1706, the proprietors being free to enter it and cut fuel and timber to supply their needs. At the date mentioned the tract was divided among the land-owners. It is a region

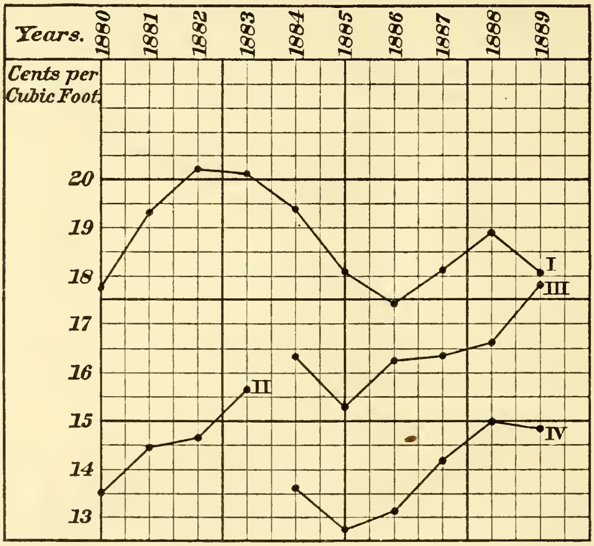
of rock-ribbed hills with bold ledges and precipitous crags, the intervening glens and valleys coursed by clear and rapid brooks and rills and having in their depths extensive swamps and ponds. It is now to return to its original character of a woodland held in common, and be, in addition, a free pleasure-ground. The city council lately decided to take advantage of the public park act of Massachusetts (see report of this division, 1887, page 101), and made an appropriation of $30,000 for the purchase of the land, which, with private subscriptions, gives a fund of about $450,000 for the purpose. A board of park commissioners, evidently the right men for the place, has been appointed, and they are now taking the land by right of eminent domain. The park commission, the water board, and the public forest trustees will act in harmony in the administration of the region as a public forest—which it will be pure and simple, with no attempt to incorporate the ordinary park features into its plan. There are about 800 acres to be taken, which, with that already held by the forest trustees and that taken by the water board—including 200 acres in the ponds—will make a total of about 1,400 acres, which may be still further increased. This forest will be the largest area dedicated to park purposes in New England. As a writer in Garden and Forest has said: "Lynn has thus led the way in establishing the first public forest, and thus set a noble example which ought not to be without effect upon other communities."

EXPORT AND IMPORT STATISTICS.

The limited space allowed for this report necessitates the omission of the usual compilation of the tables showing the amounts of imports and exports of forest products. To give, however, in condensed form some matter of interest in this direction, the following diagrams have been prepared, showing the range in our export trade during the last twenty-five years. It will be noticed that the entire exportation of all crude and manufactured products which are derived from the forest has increased rapidly and been nearly doubled. During this time we have sent abroad, in round numbers, $720,000,000 of forest products or $28,800,000 a year; when the bulkiness of the material is considered, not a mean amount. It will also be noticed that the increase of exports is less in the wood manufactures than in the crude products; while in the range of prices per cubic foot for the last ten years it appears most striking that while the price for timber, *i. e.*, manufactured in the log or roughly sawn and hewn, has constantly risen and appreciated about 40 per cent. the price for manufactured lumber at the beginning and end of the period is almost the same.

Range of average export prices of timber and lumber for ten years.

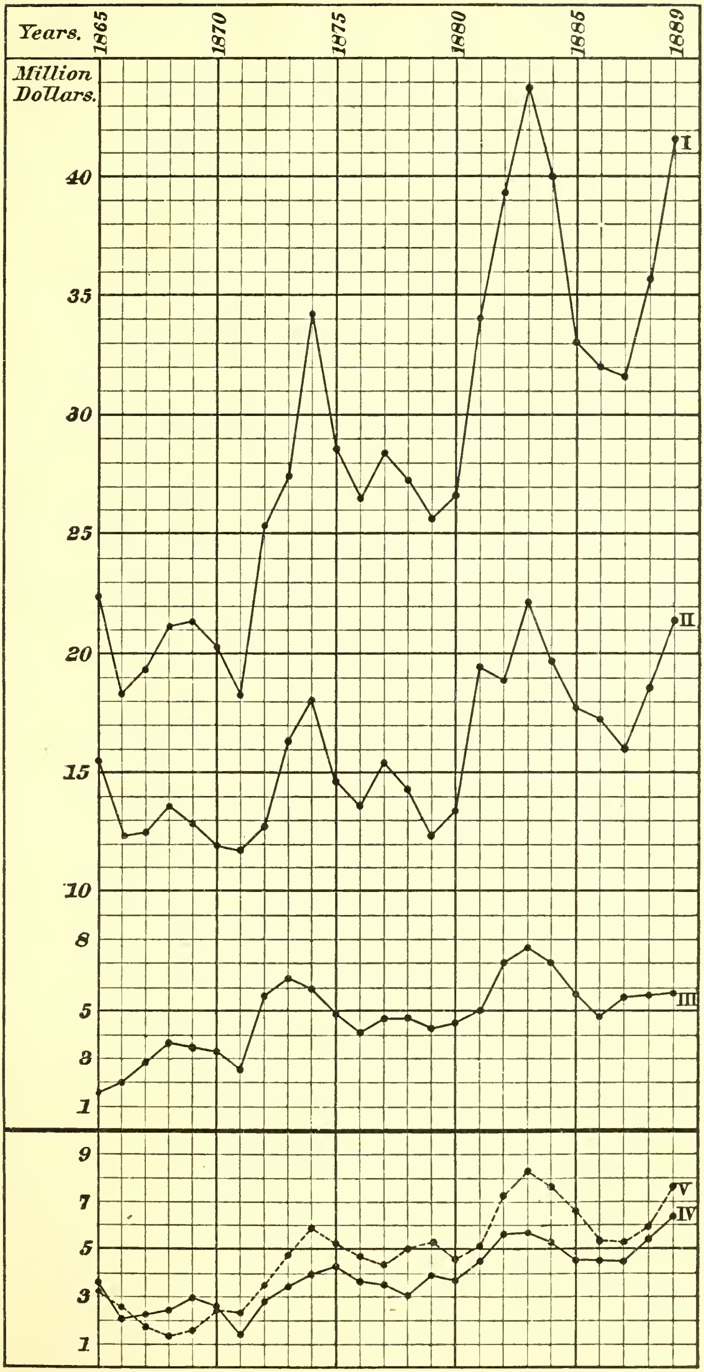
I. Prices for lumber reduced to cubic feet.
II. Prices for timber hewn and sawn, combined.
III. Prices for hewn timber.
IV. Prices for sawn timber.



Range of exports of forest products for twenty-five years from 1865 *to* 1889.

I. All forest products, crude and manufactured.
II. Lumber, timber, and partly manufactured wood products.
III. Naval stores.
IV. Wood manufactures, wholly of wood.
V. Manufactures partly of wood.

NOTE.—The summary of exports on opposite page, in addition to the materials given in the summary of the Bureau of Statistics as "Wood and its manufactures," properly includes the following products, being entirely or in their material largely derived from the forest: Naval stores, bark and tanning extracts, ashes, ginseng, sumac, together with matches, agricultural implements, carriages, cars, and musical instruments.


Years.
1865
1870
1875
1880
1885
1889
Million Dollars.
40
35
30
25
20
15
10
8
5
3
1
9
7
5
3
1
I
II
III
V
IV

PROPOSED WORK.

Without arguing what the Forestry Division of the National Government should be—namely an executive department, managing the forest lands which belong to the nation and should remain under its control, if it is simply to act as a bureau of information, it can not be difficult to conceive what the information required and what the methods of obtaining it should be for any one who will inspect my report for 1887, in which I have at length outlined a system of the science of forestry, enabling the student to form an idea of what is comprised in that science.

The division must keep in view the requirements of three classes of inquirers wanting information:

(1) The Government needs information which may serve for basis of its action in reference to its own timber lands and toward the forestry interests of the country in general. The general public naturally is desirous of the same kind of information, and both the public and the legislators need the education which will allow them to appreciate the true position of forests and forestry in the economic life of the nation.

(2) The consumers of forest products need information which will aid them in an economical and advantageous use of the same.

(3) The producers of forest products need information—if owners of natural woodlands—in regard to the best methods of utilizing these properly and managing them for reproduction; if forest planters, in regard to the best methods of starting and cultivating a timber crop.

There are two general classes of information wanted to influence and direct the action of these three classes of inquirers:

A. Information of a statistical nature, which, in the main, serves as the economic basis for action on the part of Government and individuals; and

B. Information from the field of physical and natural sciences, to serve as a basis for productive application in forest management and forest utilization.

A. Statistical information forms the only true basis for Government action with reference to forestry interests. Such action is dictated by two premises, namely:

(1) That forest supplies are apt to run short or deteriorate if left unconditionally to private discretion.

(2) That forest conditions influence climatic and cultural conditions.

The action of Government with reference to its own holdings is also influenced, besides these two considerations, by its duty as a manager of valuable property.

ad 1. The natural forest area of valuable material seems to diminish or deteriorate, (*a*) under the clearing for agricultural use; (*b*) under the action of fire and cattle; (*c*) under methods of utilization which prevent natural reforestation with valuable material.

The forest area increases (*a*) by natural recuperation of culled woodlands; (*b*) by relapsing of worn-out and abandoned fields into forest; (*c*) by forest planting.

There arises, then, a series of questions, which may be solved by statistical inquiry into the area and condition of forests, their present yield and future promise, the progress of deforestation by various agencies, and the progress of reforestation.

ad 2. Location of forest areas and their composition determine largely their value as factors of climatic and cultural conditions. Their influence is claimed in protecting soil against abrasion, in regulating water flow, in determining atmospheric and soil humidity, in diminishing deleterious action of winds, decreasing the rate of evaporation, etc.

The questions formulated under this head are partly statistical, partly belong in the field of scientific inquiry.

Statistical information is also wanted by the consumer and producer of forest products in so far as this influences their trade relations. The information supplied in answer to the questions formulated *ad* 1 will have to be further specialized and amplified for this class of inquirers.

B. Besides such information, resting upon scientific inquiry, as will aid in establishing the relation of forests to climatic and cultural conditions, there are wanted two distinct classes of information, which may be termed (1) technological, and (2) biological, more or less connected and interdependent:

(1) The consumer of forest products is mainly interested in the "dead material," the technology of woods, the possibility of their application for various purposes, the methods of prolonging their durability, substitutes, and economies in their use.

(2) The producer of forest products—the forest owner and forest planter—is concerned in the "living tree," in the life history of our timber trees, upon which to base his practices of forest management and forest planting. He wants to know what trees are adapted to his soil and climate, what trees are most profitable, what methods of starting and managing the crop promise best results.

The most pressing questions, which ought to be answered more specifically than can be done with the information on hand, are those which relate to the present conditions of our forest area, and more especially—

(1) That part which furnishes the bulk of our lumber supply and is believed to be waning—the white pine forests of the North;

(2) That part which is owned by the General Government and needs special consideration from its bearing upon water conditions in the arid regions; and

(3) The condition of supplies for special industries dependent on forest products, namely, the carriage and wagon and implement manufactures, the cooperage industry, the tanneries, the pulp manufacture, etc.

The question of general forest conditions and their change might possibly be answered through the regular staff of correspondents employed by the statistical division. The forest conditions of the timber lands belonging to the General Government might possibly be ascertained by co-operation with the agents of the United States Land Office.

The statistics of the white pine and hard-wood supplies for special industries can only be ascertained by special agents.

I repeat that Government action can rationally be based only upon carefully obtained and digested statistics; that forestry statistics are among the most difficult to gather, and that their collection is the more desirable on account of the difficulty of estimating and comparing present supplies and future requirements.

The gathering of comprehensive statistics, which alone can be of value, would necessitate an entire reorganization and such enlarge-

ment of the force of the division as may perhaps not be contemplated in spite of the desirability and urgency of this work.

Meanwhile the condition and requirements of the various industries depending upon forest products may be ascertained by special inquiries through letter and circular.

Outside of these lines of statistical inquiry there remain two most fruitful lines of work, namely, to obtain reliable information in regard to our timber trees in biological and technical direction, and to furnish by experiment a solution of the problems of timber planting on the treeless plains and arid regions.

It is a curious fact that we are by no means certain as to the qualities of our timber trees, and their consequent adaptability to various uses; still less do we know upon what conditions of soil and climate, which vary greatly with the same species, these qualities depend. Not only is the engineer interested in information on this point, but also the forest planter, for he may be led to plant a species which, while it may grow well in his locality, in the end does not develop the quality for which it was originally prized.

The systematic and comparative study of the properties of our most important timber trees, which has been begun in a small way, should therefore be continued with better facilities. The proper methods of carrying on these studies I have dealt with in former reports.

We know also very little about the life history of our timber trees, a knowledge which must be had before successful forestry can be carried on. While a certain amount of knowledge of the requirements of various trees in the nursery and for ornamental planting exists, it must not be overlooked that the behavior of the tree in the forest, and consequently its treatment by the forester, differs greatly from that in the open ground; besides, as forestry means tree culture for profit, it is very essential that the rate of growth of the various species at various ages through their whole life be known, that it be known at what age the desired quality and a profitable size may be reached, etc. The practical value of this knowledge will at once be appreciated when we look at the many black walnut plantations in the Western States which, having deceived their owners by the rapid growth of the first ten or fifteen years, are now a source of disappointment by their later slow growth; or when we see the deterioration of the soil and consequent retardation of growth, due to the planting of a thin-foliaged species by itself, when, in mixture with a shady companion, the growth would have been acceptable.

The continuation and extension of the biological studies referred to above must therefore form another direction of work, to be vigorously followed up.

There is no part of the country for which information in regard to forest planting is more needed than for the Western treeless plains and prairies. The settlers have struggled to learn what they could in this direction; they have spared no energy and braved failures; they have gathered experience, and yet, after many years of haphazard trials, there would be few who could give positive and incontrovertible evidence as to the best methods of planting and the best timbers for planting in those regions. Opinions differ as widely in the one direction as in the other.

It is therefore desirable to begin systematic experimental plantations to settle, as far as possible, these questions.

In fact, no better method of both gaining and giving information

can be devised than the practical demonstration of means and methods placed before the people right where information is most needed.

I would therefore propose to seek the co-operation of the Experiment Stations now existing in the treeless regions, and that of private individuals who can offer special facilities, in order to establish such experimental plantations upon a uniform and centrally directed plan. It would also be desirable to seek the co-operation of the authorities having charge of the military reservations in the West for a similar purpose.

From such stations it would eventually be possible to distribute plant material, as has been done successfully by the California Agricultural and Forestry Stations and elsewhere.

A desirable expenditure in the same direction would be the establishment of a national arboretum at Washington, for the purpose of collecting the timber trees that can be acclimated here. Besides many reasons of expediency, among which the educational character of such an institution in connection with this division is a potent one, the location of such an arboretum at this place recommends itself on account of the climatic conditions, which will allow to grow here in the open a greater range of arborescent plants—from the Long-leaf Pine of the South to the Spruce and Hemlock of the North and the conifers of the Pacific coast—than almost any other locality in the East.

B. E. FERNOW,
Chief of the Forestry Division.

INFLUENCE OF FORESTS ON WATER SUPPLIES.

It has been found by experience that in every department of human development nature's way of disposing of her forces is not specially favorable to progress, and that art and man's ingenuity can greatly improve upon nature, making her forces more efficiently subserve human needs.

It appears now quite certain that those countries which do not rely upon the disposition of rain-fall and snow-water as produced by the accidental and changeful, uncontrollable, and partly unknown conditions of climate, but which dispose of them in an artificial manner guided by human ingenuity, namely, by irrigation systems, produce with much greater certainty and abundance.

This once recognized, the proper distribution of the available water supplies will everywhere—not only in the arid regions—become a question of immediate interest.

Human effort in this respect can, however, not go beyond the laws of nature; it can only direct her forces and apply her laws for a given purpose. To do this, a clear understanding of the laws and forces as they are at work when left to themselves, will give us an insight as to where we can produce modifications in their working, where we may and where we may *not* expect to be successful in changing their directions.

To contribute towards such an understanding of the forces and laws which influence the natural distribution of water supplies, and

especially of the function which the forest may or may not perform in this distribution, the following pages have been written.

The water capital of the earth consists of two parts, the fixed capital and the circulating capital. The first is represented not only in the waters on the earth but also by that amount of water which remains suspended in the atmosphere, being part of the original atmospheric water-masses which, after the rest had fallen to the cooled earth, remained suspended and is never precipitated.

The circulating water capital is that part which is evaporated from water surfaces, from the soil, from vegetation, and which after having temporarily been held by the atmosphere in quantities locally varying according to the variations in temperature, is returned again to the earth by precipitation in rain, snow, and dew. There it is evaporated again, either immediately or after having percolated through the soil and been retained for a shorter or longer time before being returned to the surface, or, without such percolation, it runs through open channels to the rivers and seas, continually returning in part into the atmosphere by evaporation. Practically, then, the total amount of water capital remains constant; only one part of it—the circulating capital—changes in varying quantities its location, and is of interest to us more with reference to its local distribution and the channels by which it becomes available for human use and vegetation than with reference to its practically unchanged total quantity.

As to the amount of this circulating water capital we have no knowledge; hardly an approximate estimate of the amount circulating in any given locality is possible with our present means of measurement; for it appears that so unevenly is the precipitation distributed that two rain-gauges almost side by side will indicate varying amounts, and much of the moisture which is condensed and precipitated in dews escapes our observation or at least our measurements entirely.* Thus it occurs that while the amount of water calculated to be discharged annually by the river Rhone into the sea appears to correspond to a rain-fall of 44 inches, the records give only a precipitation over its water-shed of 27.6 inches. Even the close calculation given in my last report of the waters of the upper Elbe, according to which they drain one-fourth of the total rain-fall, calculated by the ingenious methods of Professor Studnicka, does not inspire confidence.

We must therefore enter into our discussions acknowledging ignorance of one of the most important factors, at least as to its numerical or quantitative value.

The distribution of the circulating water capital is influenced by various agencies. The main factor which sets the capital afloat is the sun, which, by its heat and the air currents caused by it, and by

*A few experiments on condensation of aqueous vapor made by L. Hampel with forest tree leaves are of interest:

	Centigrams.
Austrian pine (4 needles), condensed per day in the average	4.84
Linden (one leaf), condensed per day in the average	24.40
Oak (one leaf), condensed per day in the average	25.56
Spruce (a branchlet), condensed per day in the average	9.80

The linden, of which one leaf condensed 24.40 centigrams of dew, had 1,763 leaves. It would, therefore, if all leaves had done the same, which is to be sure not the case, have condensed 430 grams.

On grass the amount of dew per year was found by G. Dines to be 27 millimeters, *i.e.*, if collected an amount corresponding to 27 millimeters height of water would have resulted.

the rotation of the earth, produces the evaporation which fills the atmosphere with vapor. Anything, therefore, that influences the intensity of insolation, the action of the sun, or obstructs the passage of winds, must influence the local distribution of the water capital. The great cosmic influences which produce the variability of all climatic conditions, and therefore also of the circulating water capital, are the position of the earth's axis to the sun by which the angle and therefore the heat value of the sun's rays vary in different parts of the earth and at different times of the year; the distribution of land and water areas, which produces a difference of insolation because the water has less heat capacity than the land, and which also influences the direction of air and sea currents; the configuration of the earth, by which the density of the atmosphere is made unequal, and in consequence of which differences of insolation and of air temperature are induced. Thus we have not only climatic zones, but also continental climates and mountain climates in opposition to coast climates and plains or valley climates.

While this classification of cosmic climates satisfies the climatologist, there are many local climates to be found within the range of the cosmic, and the local climatic conditions are those which affect human life and human occupations most sensibly.

The same causes, different only in degree, which modify the cosmic climates, making a classification of the same possible, effect further modifications and give rise to local climates; these causes are different in the degree of insolation, obstruction to air currents, presence of water surfaces, or moisture-laden air-strata.

Among the factors which thus modify the cosmic climate and help to produce a local climate differing from other local climates, the soil-cover and especially the presence of forest areas is claimed as one that, under certain conditions, is potent; and this factor being under the control of human agency more than any other possible modifier of climate, must therefore be of greatest interest to us.

In the discussions which have prevailed hitherto, it has always been overlooked that the idea of what constitutes a forest is not only an exceedingly variable one, but that without a definite understanding of what constitutes the forest we cannot discuss its influence. It is clear, from what has been stated so far, that the influence of the forest, if any, will be due mainly to its action as a cover protecting soil and air against insolation and against winds. That the nature of a cover, its density, thickness, and its proper position has everything to do with the amount of protection it affords everybody will admit. A mosquito net is a cover, so is a linen sheet or a woolen blanket, yet the protection they afford is different in degree and may become practically none. It will also be conceded that it makes a great difference whether the cover be placed before or behind the wind. Just so with the influence of the forest; it makes all the difference whether we have to do with a deciduous or coniferous, a dense or an open, a young low or an old high growth, and what position it occupies with reference to other climatic elements, especially to prevailing winds and water surfaces. In the following discussion, when the word forest is used, unless differently stated, a dense growth of timber is meant.

Hitherto the discussion of forest influences has relied mainly upon general observations and the recital of experiences from which such influences are inferred. From the complication of causes which produce climatic conditions, it has been always difficult to prove,

when changes of these conditions in a given region were observed, that they were permanent and not due merely to the general periodic variations which have been noted in all climates of the earth, or that they were due to a change of forest conditions and to no other causes; hence some climatologists have thought proper to deny such influences entirely. On the other hand there are as trustworthy and careful observers who maintain the existence of such influences; but only of late has the question been removed from the battle-field of opinions, scientific and unscientific, to the field of experiment and scientific research, and from the field of mere speculation to that of exact deduction. But the crop of incontrovertible facts is still scanty and further cultivation will be necessary to gather a fuller harvest and then to set clear the many complicated questions connected with this inquiry.

Yet the question of the relation of forest cover to water supplies has become of such immediate concern, in our endeavor to develop the arid or subarid regions of the West with the aid of irrigation, while forest destruction, by fire more than by the ax, has bared the hills and mountains of their forest cover and their forest floor, that it seems timely to rehearse what we do actually know of this relation.

The question of forest influence on water supplies can be considered under three heads, namely: Influence upon precipitation or distribution of atmospheric water; influence upon conservation of available water supplies; influence upon the distribution or "run-off" of these supplies.

INFLUENCE UPON PRECIPITATION.

Whether forest areas are or are not capable of appreciably increasing precipitation within their limits or on neighboring ground is still a matter of dispute, and the complexity of the elements which must enter into the discussion has so far baffled solution based upon definite and strictly scientific observation. Yet new evidence is accumulating all the time, which *apparently* shows that under certain conditions forest areas obtain larger precipitations than open grounds, that is, they increase at least the amount of precipitation over their own immediate and near-lying areas. Of the prominent meteorologists who believe in such an influence is the well-known Russian, Dr. A. Woeikoff, from an unpublished translation of whose latest publication, "Climates of the Earth," written in the Russian language, I am enabled, through the courtesy of Professor Cleveland Abbe, to quote:

> The problem of the influence of forests on the amount of precipitation eluded for a long time an accurate solution, not only because the effect is extremely variable both from year to year and from place to place at short distance, but also on account of the modifying influence of local conditions. It was therefore necessary to select the conditions for such observations, so as to render the results mutually comparable. At the present time the best observations made are those made in the neighborhood of Nancy, France. The instruments and their disposition were identical at the different stations. The situation of the stations was as follows:*
>
> *Station A* (Cinq-Franchées), 8 kilometers west of Nancy, *in the midst of extensive forests* (La Haye), *growing on a plateau of lower oölite formation. Height above the sea-level* 380 *meters.* The rain-gauge is placed in an open glade of several hectares of area.

*The information is derived from Mathieu's *Relevé des Observations de Météorologie agricole et forestière*, in the *Atlas Météorologique de l'Observatoire de Paris*, 1887.

Station B (Bellefontaine), 6 kilometers northwest of Nancy; 240 *meters above the level of the sea*, in a valley running from southeast to northwest, on the margin of the La Haye forests. The rain-gauge is placed outside the woods, in a nursery.

Station C (Amance), 10 kilometers northeast of Nancy, near the summit of a hill of the lower oölite formation, 380 *meters above the level of the sea. The surrounding country while not entirely destitute of woods is chiefly occupied by fields.* Thus, at least for the Stations A and C, *both the elevation above the sea and the geological formation are the same.* Besides, the surroundings of Nancy are not mountainous and consist mostly of low plateaus more or less washed out by the water. Such localities are also frequently found in European Russia. A is a forest station, C a field station; B is on the verge of the forest and at a lower level. The following table gives the amount of rain-fall, in centimeters, for the seven years 1867, 1868, and 1872, 1873, 1874, 1875, and 1876:

Time of observations.	Station A (forest glade), 380 meters.	Station B (forest verge), 240 meters.	Station C (field), 380 meters.
	Cm.	*Cm.*	*Cm.*
February to April	15.9	16.2	14.9
May to July	18.9	17.1	16.6
August to October	20.7	17.2	15.7
November to January	21.2	18.8	17.7
Year	76.7	69.3	64.9

Comparing Stations A and C, we see that much more water falls on the forest glade than in the open fields, and that the difference is least in early spring.

Of the eighty-four months for which I have the data, sixty-three give more water at A than at C; two, the same quantity; and only nineteen more at C than at A. It further appears from an examination of the table for the separate months, that the greater quantity at A is not due to more copious and frequent heavy showers, giving a great amount of water on a small area. I found only three months, July, 1872, and July and August, 1875, in which the great difference between A and C would point to such showers as cause. Including these months, we have:

A in July 7.2, in August 6.2.
C in July 6.8, in August 4.0.

Excluding the same we find:

A in July 7.0, in August 4.8.
C in July 6.7, in August 4.0.

And in the annual mean,

A 75.1, C 64.8.

The Station B occupies a middle position between A and C, which again shows that the difference between A and C is due to the influence of the forest vegetation.*

The fact of the increase of precipitation by forests requires an explanation. I shall first consider climatic conditions as they are found in central and northern Europe, beginning with the conditions prevailing in winter. It would appear as if in winter the difference in the amount of rain-fall within and without the woods can not be great, as the absolute amount of vapor is small and the difference between the relative humidity within and without the woods is insignificant. This is however not the case, for two reasons. First, the clouds float in winter at a lower level than in summer; hence the mechanical resistance presented by the woods is more effective in winter, as it can more easily reach the strata of the atmosphere in which the clouds are moving. This resistance causes the air to rise and thus favor the formation of precipitation. Secondly, in winter the prevailing winds are generally charged with moisture and precipitation is of longer duration, so that the above-named causes act for a longer time.

In the spring and the beginning of winter the woods contribute more or less to the increase of precipitation. At this time of the year evaporation is very actively going on outside of the woods on the surface of the meadows and fields. During the winter the soil has been well stocked with moisture, which is now evaporated by the action of the processes of vegetable life and the direct access of the sun. *It is probable that during this period both the possible and the actual evaporation are*

* See also Fautrat' spaper "*Influence des bois feuillus et résineux*" Comptes Rendus, vol. 85, p. 340.

greater without than within the forest, evaporation being here understood as the sum of all water evaporated both by the soil and the plants from a given area.

In the middle of summer or toward the beginning of autumn the soil outside the woods begins partly to dry up and can not any more yield as much moisture for the evaporation of the plants as in the beginning of summer; on the other hand the vegetable processes following upon the blooming (the ripening of the seeds) require less moisture. But in the leaved woods evaporation continues in full force to the end of the summer, and in coniferous woods the evaporating surface remains approximately the same in the course of the whole year; at the same time the moisture preserved in the soil through shade and protection from wind continues to furnish sufficient material for evaporation. Consequently, just at the time when meadows and fields begin to evaporate less, it goes on as before in the forests. This gives rise to a great difference between the amount of moisture contained in the air within and near the woods, and outside of the woods in open places. Moist air more easily reaches the point of saturation and condensation than dry air.

The following point is also to be noticed. Forests, especially pine woods, must condense a great deal of moisture in winter when air nearly saturated with vapor passes over them; this gives rise to copious formations of hoar frost, which will fall to the ground and increase the mass of snow in the woods. This phenomenon has never been accurately observed and measured; but careful observation will convince anybody that wherever the temperature for several consecutive months remains below zero (as is the case in northern and eastern Europe), a considerable amount of hoar-frost is in this way collected, since the air is highly charged with moisture, and besides, the average force of the wind is greater in winter than in any other season.

In hot and moist climates where the absolute amount of vapor in the air is great (for instance in many tropical countries), the enormous surface presented by the leaves of forest trees condenses a great quantity of water on every clear and calm night, so that this water can not be retained on the leaves and falls to the ground; the observer gets the impression of a heavy rain-fall.* Thus, a certain part of the moisture evaporated by the leaves during the day returns at night, and the dew is so copious as to moisten the soil under the trees.

The observations made in the neighborhood of Nancy are at present the only proof that not only above trees but also over forest glades the precipitation is greater than in the midst of extensive fields; if, however, this phenomenon has once been clearly proved, it can hardly be doubted that it recurs at other places. In order to prove that influence of forests does not exist or that forests tend to decrease the amount of precipitation, it would be necessary to present observations made under conditions which would render them as easily comparable as those described by me above.

The author then proceeds to discuss the influence of forest areas in tropical and subtropical countries, which he finds still more marked. Conditions in India are exhibited in the following table:

Influence of forest areas on rain-fall in India.

Name of place.	Distance from the sea.	Mean temperature.				Extreme maxima.*	Relative humidity.				Precipitation.			
		April.	May.	June.	July.		April.	May.	June.	July.	April.	May.	June.	July.
Woodless country:	*Kms.*										*Cms.*	*Cms.*	*Cms.*	*Cms.*
Lucknow	847	30.1	33.3	33.1	30.4	45.8	30	36	54	74	0.5	1.8	13.3	39.4
Benares	590	30.2	33.2	32.8	29.7	45.0	41	60	81	82	0.5	1.3	12.9	32.4
Patna	445	30.3	31.4	31.4	29.2	44.6	....	....	....	....	1.0	2.5	16.9	27.8
Barhampur	270	29.6	30.1	29.2	28.7	44.1	52	60	75	79	5.6	10.1	24.2	25.8
Wooded country:														
Goalpara	427	25.2	25.9	26.9	27.7	35.1	66	77	85	84	14.8	33.6	64.3	50.0
Sibsagar	555	23.5	25.3	28.2	28.5	35.6	81	82	83	83	25.9	30.8	39.5	40.6

*Mean of two years.

A glance at this table will show *that the presence of woods has a far greater influence in mitigating the temperature during the hot and dry months of April and May than the proximity of the sea. The same is true of the relative humidity,*

* This was specially pointed out by the celebrated Boussingault, who observed it in South America.

especially at Sibsagar, *i. e.*, *in the middle of the forests. Most striking is the effect of the presence of woods in the diminution of the extreme maxima. The greater or less proximity of the sea has but little effect, but as soon as we reach the wooded region the extreme maximum falls* 9 *degrees.* Thus in 1875 the maximum thermometer did not rise above 35.3 degrees at Goalpara, while at Lucknow there was not a single day from March 14 to June 22 on which a higher temperature had not been observed. The great humidity of the air even during the hot and dry months of April and May is the cause why, in the forests, the rains begin early in March and gradually increase in intensity until June or July, while in the woodless plains of the Ganges the amount of rain-fall suddenly increases from May to June or from June to July.*

It is also noteworthy that *the distance between Benares and Goalpara is* 760 *kilometers, the latitude is nearly the same*, the intervening country is level, the distance to the sea is in both cases considerable; and yet the mean temperature of May differs 7.4 degrees Fahrenheit, or about 1 degree centigrade per 100 kilometers. *At no place on the earth*, for which we have observations, has *such a difference of temperatures ever been observed under similar circumstances.* It is, however, to be observed that we have but few good observations in the tropics and in latitude below 30 degrees, especially in the interior of continents. It may be expected that in South America, where in nearly the same latitude extensive prairies (Llanos) and dense virgin forests can be found, similar differences of temperature may be observed in the same months (April and May).

At the present time there are in the basin of the Amazon four stations where observations are made; this river-basin is the most extensive forest region on the earth. The middle and upper portion of the course of the Amazon is over 1,000 kilometers distant from the Atlantic Ocean, while it is separated by mountains from the Pacific. Were it not for the forests we ought to expect, at this distance from the sea and so near the equator, very high temperatures and great dryness. The following table shows the results of the observations:

Difference of temperature of four stations in the basin of the Amazon.

Name of station.	Height above sea.	South latitude.	Distance from Atlantic.	Temperature.			Relative humidity for the year.
				Annual mean.	Mean of hottest month.	Extreme maxima.	
	Meters.	*Degrees.*	*Kilom.*				
Para*	....	1½	100	27.0	27.7	....	....
Manaos	37	3	1,150	*26.1	27.0	*35.7	*80
Iquitos	95	3½	2,100	24.8	25.7	32.4	83
Pernambuco†	3½	8	0	25.7	27.1	31.7	72
San Antonio on Madeira River	....	9	1,750	26.0	27.0	....	....

* Ten months, from October to July.
† Pernambuco does not belong to the Amazon basin; its means are only given for comparison with those of San Antonio. The shore-line near Pernambuco is wooded, but a certain distance around the city the forests are cut down to give way to fields and sugar-cane plantations.

Thus, owing to the vast primeval forests on the Upper Amazon and its tributaries, the temperature of the hottest month and the extreme maximum are not greater than on the sea-coast: and the extreme maximum is far from reaching the values sometimes observed in middle latitudes. It is also to be observed that there are few regions on the earth where the "Trades" blow with such violence as on the coasts of northern Brazil; Pernambuco is therefore subject not only to the influence of the sea but also to that of a furious trade-wind. Along the lower course of the Amazon the "Trade" also blows with great force; but as soon as we turn into the side valley of one of the tributaries running in a southerly and northerly direction calm weather is found to prevail. The height and density of the forest arrests the wind. There can be no doubt that the vast tracts of forest land on the Amazon, contributing to maintain the moisture of the air and weaken its motion, increase

* As regards the great difference of climate between Assam and the plains of the Ganges, the Indian meteorologist, Blanford, informs me by letter that he attributes this difference, *i. e.*, the greater moisture of the air, the lower temperature from April to June, and the early beginning of the rains observed at Assam, to the vast dense forests covering the country.

the amount of water-fall. At Iquitos 284 centimeters fall in the course of the year. It must be remembered that Iquitos lies in a plain 2,100 kilometers from the ocean and 350 from the mountains; nowhere on the earth is the rain-fall so great under similar circumstances.

Without further discussing the influence of the forest upon quantity and distribution of rain-fall, we may say that many observations and the philosophy of meteorological forces lend countenance to the following statements:

(1) During the time of vegetation large quantities of vapor are transpired and evaporated by a forest, by which the absolute humidity of the air above the forest is increased; and since, on account of the cooler temperature which prevails over and within a forest, the relative humidity is also greater, the tendency to condensation is increased.

(2) This moister and cooler air stratum communicated to the neighboring locality must increase the dew, at least, over the neighboring field.

(3) This relatively moister air stratum, carried away by air currents, has the tendency to induce precipitation at such places, especially where the additional influence favorable to precipitation—namely, increased altitude—exists; therefore,

(4) While the forest may not *everywhere* increase precipitation over its own area, yet a large system of forests over an extensive area will influence the quantity of precipitation over and within this area.

(5) It must never be overlooked that there are certain rain conditions prevailing in climatic zones (rainy or rain-poor localities, with periodical, seasonal, or irregular rains) which are due to cosmic influences and can not be altered, but may be locally modified by forest cover. Hence, experiences in one climatic zone can not be utilized for deductions in another.

DISPOSAL OF WATER SUPPLIES.

Given a certain amount of precipitation in rain or snow over a certain area, the disposal of the water after it has fallen, and the influence of the forest-cover on its disposal, require our attention. For the sake of convenience we can divide the elements which need consideration in this discussion into elements of dissipation, elements of conservation, elements of distribution.

The difference in effect between the first two classes of elements will give us an idea of the amount of available water supply or run-off resulting from precipitation; while the third class bears upon the methods of distributing the available water supply.

ELEMENTS OF DISSIPATION.

Elements of dissipation are those which diminish the available water supplies; they are represented in the quantity of water which is prevented by interception from reaching the ground, in the quantity dissipated by evaporation, in the quantity used by plants in their growth, and in transpiration during the process of growing.

Interception.—The amount of rain-fall and snow which is prevented by a forest growth from reaching the soil varies considerably according to the nature of the precipitation and to the kind of trees which form the forest as well as the density and age of the growth.

A light drizzling rain of short duration may be almost entirely intercepted by the foliage and at once returned to the atmosphere by evaporation; if, however, the rain continues, although fine, the water will run off at last from the foliage and along the trunks.* And this amount, of which the rain-gauge takes no account, represents, according to measurements of the Austrian stations, from 8 to 14 per cent., thus reducing considerably the loss to the soil.

While the careful measurements at the Swiss stations in a twelve years' average show the interception in a larch forest as 15 per cent., in a spruce forest 23 per cent., in a beech growth 10 per cent., the figures for the Prussian stations are for beech growth 24 per cent., for spruce at various stations 22 per cent., 27 per cent., and 34 per cent., respectively. Altogether, for the rain-fall conditions of the countries cited, a dense forest growth will, on the average, intercept 23 per cent. of the precipitation; but if allowance be made for the water running down the trunks, this loss is reduced to not more than 12 per cent.

The amount of interception in the open growths which characterize many of our Western forest areas would be considerably smaller, especially as the rains usually fall with great force, and much of the precipitation is in the form of snow. Although branches and foliage catch a goodly amount of this the winds usually shake it down, and consequently but very little snow is lost to the ground by interception of the foliage.

There is also a certain amount of water intercepted by the soil-cover and held back by the soil itself, which must be saturated before any of it can run off or drain away. This amount, which is eventually dissipated by evaporation and transpiration, depends, of course, upon the nature of the soil and its cover, especially upon their capacity to absorb and retain water.

This retentive power is called the maximum water capacity of the soil, and depends largely upon the structure and more or less compact stratification of the material. The least retentive soil is a coarse sand followed by finer sands, loams, clays, marls, and organic matter; that is to say, humous earth or vegetable litter will retain the most water. The amount of such retention, varying somewhat with the temperature, as shown in the analyses of Professor Hilgard and others, is from 1.64 per cent. of its own weight in a "second class" Florida sand soil to 23 per cent. and more in a peat soil; a pure clay rarely exceeds 12 per cent., while calcareous clay soils rise to 15 and 20 per cent.

Different from this hygroscopic water, known as "moisture co-efficient," which represents the amounts of water permanently absorbed by the soil in its natural condition, is the amount which it may hold temporarily, liable to be drained off or evaporated. According to Ebermayer, these amounts may vary from 3 to 88 per cent. According to Dr. Raman's investigations, the water capacity of sand soils of fine and medium fine texture may amount to from 3 to 4 per cent. of their own weight, or 4 to 5 per cent. of their volume in the upper strata, and 5 to 6 per cent. in the lower strata. Impermeable soil strata (loam and very fine sand) allow, when a superficial run-off is possible, only a passing and inferior retention of water after precipitation; being capable in spring-time of holding no more than 10 or 12 per

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*The maximum rain-fall observed in Germany is 4 inches in twenty-four hours and 2 inches in one hour. In Switzerland there has been recorded a rain-fall of 18 inches in twenty-four hours and 2⅕ inches in three-quarters of an hour. This would equal 5,000 gallons per acre. Of such falls the foliage will retain only an inappreciable amount. Intensity of rain-fall in the United States becomes clear from a few records: Paterson, N. J., 1½ inches in eight minutes; Sandy Spring, Md., 5 inches in 2½ hours; Clear Creek, Nebr., 4.50 inches in one hour twenty-seven minutes; Castroville, Tex., 5.80 inches in twenty-four hours; Ellsworth, N. C., 13 inches, of which 9 inches in three and one-half hours; and rain-falls from 1½ to 4 inches per twenty-four hours are quite frequently reported in almost every month, especially in the Western States, where the rain-fall is often quite explosive.

cent. of their weight, while a stratum of sand of medium grain 20 to 25 feet deep would, it was calculated, be capable of taking up and holding the entire annual precipitation of 24 inches.

As to the distribution of water in the soil, it is found that the upper humous strata contain the highest amounts, the following deeper strata the least; the water capacity then increases downwards, and at last remains stationary to a considerable depth. The capillarity of the sand soils investigated was not capable of raising the ground water higher than 1½ feet, so that the upper strata of the soil which was within reach of ground water did not show in reality greater amounts of water than the soil which had no ground water to fall back upon.

The water capacity of litter, which Wollny investigated, depends on its nature and, of course, its thickness to a certain degree, and is quite considerable, much greater than that of soils.

The water capacity of various litters was found to be as follows in volume per cent.:

Depth of litter.	Oak leaves.	Beech leaves.	Spruce litter.	Pine litter.	Moss.	Calcareous sand soil.
When 2 inches deep	50.77	....	38.93	... .	19.82	....
When 12 inches deep	45.42	39.78	41.65	36.28	....	24.93

No soil cover was found so variable in water contents as moss, while litter would hold two or three times as much water as moss and twice as much as the soil.

The variation of water capacity at different depths appears from the following figures:

Depth of litter.	Oak leaves.	Spruce leaves.
Two inches	50.77	38.98
Four inches	52.99	40.76
Eight inches	53.09	41.03
Twelve inches	45.42	41.65

That is to say, the increase in water capacity ceases with about 8-inch depth.

Altogether an appreciable amount of the precipitation does not run off or drain through the forest cover but is retained by it; yet while this is apparently a loss, we shall see further on that this moisture retained in the upper strata fulfills an important office in checking a much greater loss due to evaporation, and thus becomes an element of conservation.

Evaporation.—The loss by evaporation after the water has reached the ground depends in the first place upon the amount of direct insolation of the soil, and hence its temperature, which again influences the temperature of the air. The nature of the soil cover, the relative amount of moisture in the atmosphere, and the circulation of the air are also factors determining the rate of evaporation. The importance of this element of dissipation may be learned from the experiments of Prof. T. Russell, jr., of the U. S. Signal Service, made in 1888. We learn from these that the evaporation on the Western plains and plateaus may, during the year, amount to from 50 to 80 inches, nay, in spots, 100 inches, while the rain-fall (diminishing in reverse ratio) over this area is from 30 to 12 inches and less.

Thus in Denver, where the maximum annual precipitation may reach 20 inches, the evaporation during one year was 69 inches.

This deficiency of 49 inches naturally must be supplied by waters coming from the mountains, where the precipitation is large and the evaporation low (on Pike's Peak alone, there may be 45.6 — 26.8 = 18.8 inches to spare).

If the loss by evaporation from an open field be compared with that of a forest-covered ground, it will, as a matter of course, be found to be less in the latter case, for the shade not only reduces the influence of the sun upon the soil, but also keeps the air under its cover relatively moister, therefore less capable of absorbing moisture from the soil by evaporation. In addition, the circulation of the air is impeded between the trunks, and this influence upon available water supply, *the wind-breaking power of the forest*, must be considered as among the most important factors of water preservation. Especially is this the case on the Western plains and on those Western mountain ranges bearing only a scattered tree growth and where, therefore, the influence of shade is but nominal.

The evaporation under the influence of the wind is dependent not only on the temperature and dryness of the same, but also on its velocity, which being impeded, the rate of evaporation is reduced.

Interesting experiments for the purpose of ascertaining the changes in the rate of evaporation effected by the velocity of the wind were made by Prof. T. Russell, jr., of the Signal Service, in 1887. The result of these experiments (made with Piche's hygrometers whirled around on an arm 28 feet in length, the results of which were compared with those from a tin dish containing 40 cubic centimeters of water exposed under shelter) show, that with the temperature of the air at 84 degrees and a relative humidity of 50 per cent., evaporation at 5 miles an hour was 2.2 times greater than in a calm; at 10 miles, 3.8; at 15 miles, 4.9; at 20 miles, 5.7; at 25 miles, 6.1, and at 30 miles the wind would evaporate 6.3 times as much water as a calm atmosphere of the same temperature and humidity.

Now, if it is considered that the average velocity of the winds which constantly sweep the Western subarid and arid plains is from 10 to 15 miles, not rarely attaining a maximum of 50 and more miles, the cause of the aridity is not far to seek and the function of the timber-belt or even simple wind-break can be readily appreciated.

What the possibilities of evaporation from hot and dry winds may be, can be learned from statements regarding the "Foehn," which is the hot wind of Switzerland, corresponding to the "chinook" of our Western country.

The change in temperature from the normal, experienced under the influence of the Foehn has been noted as from 28° to 31° Fahr., and a reduction of relative humidity of 58 per cent. A Foehn of twelve hours' duration has been known to "eat up" entirely a snow cover of 2½ feet deep.

In Denver a chinook has been known to induce a rise in temperature of 57° Fahr. in twenty-four hours (of which 36° in five minutes) while the relative humidity sank from 100 to 21 per cent.

The degree of forest influence upon rate of evaporation by breaking the force of winds is dependent upon the extent and density of the forest, and especially on the height of the trees. For according to an elementary law of mechanics the influence which breaks the force of the wind is felt at a considerable elevation above the trees. This can be practically demonstrated by passing along a timber plantation on the wind-swept plains. Even a thin stand of young trees not higher than five feet will absolutely calm the air within a

considerable distance and height beyond the shelter. Unfortunately no accurate experimental data concerning this influence are at hand. According to Becquerel, a simple hedge 6 feet in height will give protection for a distance of 70 feet; and according to Hardy, a belt of trees every 300 feet will defend vegetation almost entirely against the action of the wind. Another authority finds for every foot in height one rod in distance protected.

This division has lately begun a canvass to ascertain the actual experience in regard to the value of wind-breaks on the prairies and plains. This canvass is not completed as yet, but to show what the drift of this experience is, we give an extract from the letter of one farmer in Illinois:

> My experience is, that now in cold and stormy winters wheat protected by timber belts yields full crops, while fields not protected yield only one-third of a crop. Twenty-five or thirty years ago we never had any wheat killed by winter frost, and every year a full crop of peaches, which is now very rare. At that time we had plenty of timber around our fields and orchards, now cleared away.

It may not be necessary to state that the damage done to crops by the cold dry winter winds is mainly due to rapid evaporation, and that plants are liable to suffer as much by winter drought as by summer drought.

This is certain, that since summer and winter drought, *i. e.*, rapid evaporation, due to the continuous dry winds, is the bane of the farmer on the plains, rationally disposed timber belts alone will do much to increase available water supply by reducing evaporation.

Various experiments comparing the rate of evaporation within and without a forest are recorded in the following table, which refers to evaporation from a water surface in the open field on the one hand and within the shelter of the forest on the other. It is shown that under ordinary circumstances evaporation may under forest cover be decreased from two to three times.

Evaporation of a water-surface from April to October, expressed in centimeters.

	Without the forest.	Within the forest.	Ratio.
Eastern France ....(2) ..	41.2	13.2	312 to 100
Alsatian Mountains....(3) ..	33.5	15.9	211 to 100
Bavaria ....(4) ..	37.7	15.8	239 to 100
Brandenburg..........(5) ..	39.9	16.3	245 to 100
Silesian Mountains ....(6) ..	26.7	10.6	250 to 100
Eastern Prussia ....(7) ..	25.2	12.0	210 to 100

References to table: (2) Station Belle-fontaine, (3) Station Melkerei, (4) Six Stations, (5) Station Eberswalde, (6) Station Carlsberg, (7) Stations Fritzen and Kurwien.

An experiment made in Bavaria in which soil saturated with water was used, showed the values in centimeters of evaporation for seven months—from April to October—to be as follows:

Without the forest..	40.8
Within the forest:	
Pine woods..	15.9
Deciduous trees...........	6.2

That is to say, evaporation progressed six and one-half times as fast in the open field as in the deciduous woods during the warm months.

The stations of Prussia allow the following average for evaporation; the amount evaporated in the open fallow field being called 100:

	Evaporated.	Retained more than in open fallow field.
	Per cent.	*Per cent.*
Under beech growth	40.4	59.6
Under spruce growth	45.3	54.7
Under pine growth	41.8	58.2
From cultivated field	90.3	9.7

A balance calculation of the amounts of precipitation and the amounts lost by evaporation for sixteen stations at varying elevations shows that with increasing altitude the surplus of water remaining for the soil increases, the mountain forest decreasing evaporation to its minimum of 9 to 13 per cent., and leaving from 87 to 91 per cent. to penetrate the soil.

Stations.	Altitude.	Surplus of precipitation over evaporation.		Of precipitation evaporated.	
		In the open.	In the forest.	In the open.	In the forest
	M.	*Mm.*	*Mm.*	*Per ct.*	*Per ct.*
Schoo	3	322.5	343.6	55	28
Fritzen	30	387.5	322.5	40	28
Hadersleben	34	495.8	481.4	35	20
Eberswalde	42	142.1	237.5	73	44
Lintzel	95	174.6	180.6	70	67
Average for the region	0-100	305.3	313.1	55	37
Kurwien	124	346.1	365.7	44	26
Marienthal	143	184.9	254.7	68	37
Hagenau	145	436.1	434.3	46	26
Average for the region	100-200	322.4	351.6	53	30
Neumath	340	328.5	510.9	60	23
Friedrichsrode	353	291.0	385.8	57	26
Average for the region	300-400	309.9	448.3	58	25
Lahnhof	602	850	685.2	24	15
Hollerath	612	717.5	490.2	26	21
Schmiedefeld	680	1,468.2	1,114.3	13	7
Carlsberg	690	718.8	839.1	27	10
Average for the region	600-700	938.7	782.2	22	13
Sonnenberg	774	1,196.4	1,093.8	15	9
Melkerei	930	1,142.1	1,196.8	19	11

The reason for this influence of the forest, as has been stated, is due not only to the impeded air circulation, but also to the temperature and moisture conditions of the forest soil and forest air.

From the following table appear the differences of soil temperature (centigrade) in the forest, the minus sign denoting the lower temperatures in the forest, the plus sign the higher temperatures:

Differences of temperature of the soil inside and outside of a forest.

	February–April.		May–July.		August–October.		November–January.		Year.	
	Surface.	0.9 m.	Surface.	0.9 m.	Surface.	0.9 m.	Surface.	0.9 m.	Surface.	0.9 m.
Alsatian Mountains (1)	−1.0	+0.5	−7.8	−2.8	−5.7	−3.2	+0.3	−0.7	−3.5	−1.5
Bavaria (1)	−1.8	−0.8	−4.5	−3.9	−2.6	−3.0	0	−0.1	−2.2	−2.2
Bavaria (2)	−1.3	−0.6	−4.6	−4.1	−2.6	−3.0	+0.3	−0.1	−2.1	−2.0
Eastern Prussia	−1.3	0	−4.4	−3.6	−2.3	−2.2	+1.3	+0.9	−1.6	−1.2

(1) Same stations as for preceding table on page 308.
(2) Same stations with the addition of Duschberg, Johanneskrenz, and Altenfurth.

It appears that in winter it may occur that the soil is even warmer in the forest, especially in regions which, like eastern Prussia, have cold winters and where the ground is covered with snow for several months.

The mitigating influence on the soil temperature appears still more clearly when the maximum and minimum temperatures for the year or the range of temperature is compared.

	Range of temperature.	
	Without the forest.	Within the forest.
	Degrees.	*Degrees.*
Bavaria	39.5	29.5
Alsatian Mountains	35	21
Eastern Prussia	41.8	26.7

For the air temperatures the differences are much smaller, yet in general the summer temperatures are lower and the winter temperatures are higher in the forest, and this influence seems greater in the warm climate of Italy than in the colder climate of Prussia. In the following table the maximum, minimum, and mean temperatures within forest stations are noted—the plus sign denoting higher the minus sign lower temperatures than those observed in the field stations.

	February–April.			May–July.			August–October.			November–January.			Year.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
Central Italy (1)	.....	.....	.....	−4.1	+1.6	−1.2	−3.6	+1.1	−1.3	.....	.....	.....	.....	.....	
Eastern France (2)	−0.8	+0.8	0	−3.2	+1.2	−1.0	−2.6	+1.3	−0.6	−0.9	+0.6	−0.1	−1.9	+1.0	−0.4
Alsatian Mountains (3)	−1.1	+1.9	+0.4	−2.5	+1.9	−0.3	−1.9	+2.4	−0.2	+0.9	+1.7	+1.3	−1.2	+2.0	+0.4
Bavaria (4)	−0.5	+0.2	−0.3	−2.2	+1.1	−0.9	−3.2	+1.6	−0.8	0	+1.2	+0.6	−1.5	+1.0	−0.3
Eastern Prussia (5)	−0.7	+0.1	−0.3	−1.4	+0.5	−0.4	−1.6	+0.2	−0.7	−0.3	−0.2	−0.2	−1.0	+0.2	−0.4

(1) Station Vallambrosa, Tuscany.
(2) Station Bellefontaine near Nancy.
(3) Station Melkerei, in the Vosges Mountains.
(4) Stations Seeshaupt and Rohrbrunn.
(5) Stations Fritzen and Kurwien.

The greater humidity of the atmosphere under forest cover, *i. e.*, in shade, tends also to reduce evaporation. The temperature, especially during the warm months, being considerably lower in the forest interior, the air receives less moisture in proportion from the soil and lower vegetation. A cubic foot of forest air, then, contains in the average less moisture than a cubic foot of air over a cultivated field under otherwise same conditions.

While thus the absolute amount of moisture in the forest air is really less, the relative humidity is greater; that is, the air of the forest being of lower tempera-

ture is nearer the state of saturation. The state of affairs is exhibited in the following tabulated observations:

Influence of forests, especially in summer, on the moisture of the air, expressed in percentages of the state of saturation.

[Relative humidity within and without the forest.]

	February–April.		May–July.		August–October.		November–January.		Year.	
	With-out.	With-in.	With-out.	With-in.	With-out.	With-in.	With-out.	With-in.	With-out.	With-in.
Alsatian Mountains (1)	80	85	68	75	78	84	85	89	77	84
Bavaria (2)	80	84	70	80	78	85	87	90	79	85
Eastern Prussia (3)	84	85	64	68	76	81	90	92	78	82

(1) Melkerei. (2) Six stations. (3) Fritzen and Kurwien.

The difference of temperature of the soil, and therefore also of the air, is dependent as well upon the degree of shade exerted by the forest cover as upon the nature of the soil cover. The influence of the latter has been carefully investigated by Wollny. In the following table is noted the range of temperature during the day of various soil-covers, from which it appears that the naked soil cools off during the night much more and heats up much more during the day than the various soil-covers, of which pine litter shows the next greatest range to naked soil.

	Soil, calcareous sand.	Pine litter.	Spruce litter.	Oak leaves.	Moss.
Morning temperature	13.24	14.51	15.25	15.00	14.66
Evening temperature	19.11	18.16	18.62	18.24	17.27
Range of temperature	5.87	3.65	3.37	3.24	2.57

The different rates of evaporation from various soil-covers has been carefully investigated independently by Drs. Wollny and Ebermayer. According to Wollny, the unprotected soil evaporated more than twice or three times as much as that covered with litter, while a moss-cover came very near evaporating as much as the open soil. The amounts in grams which were evaporated from a surface of 400 square centimeters during the time from June 6 to September 7 were as follows:

Loam	2,614	Spruce litter	952
Sand	2,011	Beech leaves	724
Moss	1,766	Oak leaves	725
Pine litter	959		

This difference must be accounted for by the difference in physical structure of the material, which either impedes or facilitates replacement of the water evaporated by capillary attraction. Therefore, according to the nature of the forest floor, the rate of evaporation varies.

The experiments of Wollny in 1883 on the amounts of evaporation from soil covered with straw and uncovered are also of interest here as showing the numerical influence of a cover or mulch of dead material, which does not, like the litter, possess capillary forces. The cover in these experiments was 2 inches thick; for a surface of 1,000 square centimeters the amounts evaporated were, during the months of July and August, 571 and 5,739 grams, respectively; that is to say, the naked soil evaporated more than ten times as much as the covered soil.

While in the above experiments the evaporation from the soil-cover was investigated, the Austrian Forest Experiment Stations investigated the influence of moss and litter upon the evaporation from the soil underneath. A fine sand with an average moisture of 4.82 per cent. was covered with various materials, and the amount of moisture which remained in the sand after an exposure for four months

was measured. The amounts lost by evaporation, which allow an estimate of the relative amount of protection of the various covers, were as follows:

	Per cent.
Uncovered sand	54.8
Sand covered with dry earth	40.7
Sand covered with beech leaves (vertical layers)	31.1
Sand covered with beech leaves (horizontal layers)	26.8
Sand covered with beech leaves (kept moist)	0
Sand covered with air-dried spruce litter	34.4
Sand covered with air-dried pine litter	43.6
Sand covered with living grass sod	35.9
Sand covered with living hypnum moss	27.8
Sand covered with living sphagnum moss	6.3

The soil covered with moist beech leaves not only did not lose any moisture but during the first months it absorbed water from the cover, which, however, was lost again later during the warmer weather. The last three covers were kept alive by careful sprinkling in small amounts for three months; this was, however, not sufficient to keep the grass alive to the end of the experiment. The low dense hypnum moss preserved the moisture well as long as it was sprinkled, but when allowed to dry it could do no better than the dry beech leaves. The sphagnum moss, however, continued its protective function even after the sprinkling. The pine litter in an air-dried condition showed but little power of protection; this would have been more effective if, as it occurs in nature always, it had been kept moist.

Altogether, it will have to be admitted that the factor of dissipation represented in the evaporation from the ground is considerably reduced by the forest-cover; and since the rate of evaporation in our western Territories is probably the greatest element in the dissipation of moisture, the greatest attention to checking it will be necessary in the husbanding of water supplies. This check to evaporation refers not only to the preservation of the water supply where it falls, but also in the natural and artificial channels through which it may be conducted or in the reservoirs where it may be stored.

The surface exposed determines the amount of evaporation from water-courses and reservoirs; but if the amount evaporated is related to the available volume of water, it will appear that the smaller and slower run loses proportionately more than the larger, which thus exhibits the value and protective character of accumulation.

Take a brook 6 feet in width and only a foot in depth; this for a length of 30 feet would contain 180 cubic feet of water. If from this surface only one-tenth of 1 inch evaporates, the amount evaporated is equal to 1.5 cubic feet or $\frac{1}{120}$ of the entire supply. On the other hand one-tenth of 1 inch evaporation from a river 60 feet broad and 12 feet deep for a length of 30 feet, containing therefore 21,600 cubic feet of water, would bring the loss to 15 cubic feet or only $\frac{1}{1440}$ of the available supplies; the loss, in proportion to the supply, being twelve times greater in the former case.

Transpiration.—All vegetation takes up a certain amount of water, a part of which is consumed in building up its body, and a still larger part returned to the atmosphere by transpiration during the process of growth.

The quantity of water so used is as variable as the amount of precipitation and in fact within certain limits depends largely upon it. That is to say, a plant will transpire in proportion to the amount of water which is at its disposal. Transpiration is also dependent on the stage of development of the plant, on the nature of its leaves and amount of its foliage, on temperature, humidity, and circulation of the air, on intensity of the sunlight, and on temperature and structure of the soil and on other meteorological conditions. Rain and dew reduce transpiration, wind increases it.

The amount of transpiration depends considerably upon the thick-

ness of the leaves, therefore the surface of the foliage is not a reliable measure, but it should be compared with the weight.

With so many factors to vary them the values which may be given for the amount of transpiration of the various kinds of trees can only be approximations of its range within wide limits. All the figures which have been published, based upon calculations or experiments in the laboratory, are useless for practical purposes. Especially do those figures which represent the requirement of the plant as exceeding the amount of precipitations, exhibit on simple reflection, their absurdity.

If the requirement per acre is considered, the density of the growth of plants must also be taken into account.

The first careful and comprehensive investigations into the water requirements of forest trees were made by the Austrian forest experiment stations in 1878 (F. B. Hoehnel), and full tables of the results obtained can be found in the records of those stations.

An average of the many figures there presented would make the amount of transpiration per 100 grams of dry weight of leaves in conifers 4,778 to 4,990 grams of water, in deciduous-leaved trees 44,472 to 49,553 grams of water. That is to say, the deciduous trees transpired about ten times as much as the conifers, and comparing the two extremes of transpiration, the deciduous tree with the highest rate of transpiration utilized twenty-three times more water than the coniferous tree with the lowest rate. Ash, birch, and linden were found to be the most vigorous transpirers, oaks and maples transpiring much less. Curiously enough, while in the conifers shade reduced the transpiration considerably, in the deciduous trees it had the opposite effect.

During the period of vegetation the following varieties transpired per pound dry weight of leaves :

	Pounds of water.
Birch and Linden	600–700
Ash	500–600
Beech	450–500
Maple	400–450
Oaks	200–300
Spruce and Scotch Pine	50–70
Fir	30–40
Black Pine	30–40

The next season, which was more favorable to transpiration, the amounts were larger; the deciduous trees transpiring from 500 to 1,000, the coniferous from 75 to 200 pounds, or in the proportion of one to six.

The following actual amounts transpired per 100 grams of dry leaves during the third season (1880), will show the relative position of the various species (European):

	Kilograms.		Kilograms.
Ash	101,850	Scotch Pine	12,105
Birch	91,800	Fir	9,380
Beech	91,380	Austrian Pine	7,005
Hornbeam	87,170	Aspen	95,970
Elm	82,280	Alder	93,300
Maple (*A. campestre*)	70,380	Linden	88,340
Norway Maple (*A. platanoides*)	61,180	Larch	125,600
Oak (*Q. robur*)	69,150	Average deciduous trees	82,520
Oak (*Q. Cerris*)	49,220	Average conifers	11,307
Norway Spruce	14,020		

The variability of transpiration from day to day is of wide range; a birch standing in the open and found to have 200,000 leaves was calculated to have transpired on hot summer days 700 to 900 pounds, while on other days its exhalations were probably not more than 18 to 20 pounds.

A fifty to sixty year old beech was found to have 35,000 leaves, with a dry weight of 9.86 pounds; a transpiration at the rate of 400 pounds per pound during the period of vegetation would make the total transpiration 3,944 pounds per tree (about 22 pounds daily); and since 500 such trees may stand on 1 acre, the transpiration per acre would amount to 1,972,000 pounds, while the precipitation during the same period would be 2,700,000 pounds.

The transpiration of a thirty-five-year-old beech with thinner leaves, of which there were 3,000, with a dry weight of 0.79 pounds, would under the same conditions transpire 470 pounds per 1 pound of foliage, or 373 pounds per tree (about 2½ pounds per day from June to November); and since about 1,600 such might be found on an acre, the total transpiration might amount to 596,800 pounds per acre, or considerably less than the amount of rain-fall.

Calculated for summer months during June, July, and August alone, the requirement of the two beech growths was 20,000 and 5,000 pounds per day an acre respectively. Conifers, as was stated, transpire one-sixth to one-tenth of the amount which is needed by deciduous trees.*

I repeat again that these figures can only be very rough approximations denoting maxima of transpiration, and that the amounts transpired per acre depend largely on the amounts furnished by precipitation. Therefore our forest areas within the arid region of the country probably transpire a minimum of water, their scattered growth and their coniferous composition, with the scanty rain-fall, reducing the amounts to lowest limits.

Taking a rain-fall of 20 inches, which represents say 4,500,000 pounds of water per acre, a coniferous forest, assumed to transpire one-sixth of the amount found for the older beech-forest under most favorable conditions of precipitation, would require hardly more than 330,000 pounds (presuming the same weight of foliage), or not 8 per cent. of the total precipitation. To be sure, this amount must be available during the period of vegetation.

Since this water is given off again to the atmosphere in the locality where it has fallen—thus re-enriching the atmospheric moisture—it may be considered as part of the circulating water capital which

*The amounts transpired by agricultural crops and other low vegetation, weeds, etc., have been found to be considerably larger, as will be seen from the results of the latest investigations by Wollny, which I have calculated per acre to make them comparable with the foregoing results:

Agricultural crops.	Time of vegetation.	Water consumption per acre.
		Pounds.
Winter rye	Apr. 20–Aug. 3, 1879	2,590,186
Barley	...do	2,720,238
Peas	...do	3,144,128
Red clover (first season)	Apr. 20–Oct. 1, 1879	3,070,012
Summer rye	Apr. 20–Aug. 14, 1880	3,000,486
Oats	Apr. 20–Sept. 14, 1880	3,422,584
Beans	Apr. 20–Sept. 10, 1880	3,139,233
Red clover (second season)	Apr. 20–Oct. 1, 1880	4,109,198

does its duty in producing useful substance and in conserving moisture for the locality.

There is still to be considered a certain amount of moisture which is retained and stored up in the body of the plant, partly as a necessary permanent constituent, partly as a temporary constituent, being evaporated when the plant dies or the wood is seasoned. The amounts thus retained vary considerably according to age, capacity for transpiration, site, soil, climate, density, slow or rapid growth, weather, seasons, and even the time of the day. It is therefore almost impossible to give anything but very rough approximations, especially as also the different parts of the tree vary considerably in the amounts of water present.

The water which enters into chemical composition of the wood substance represents round 50 per cent. of the weight of dry substance.

The water hygroscopically retained in the living tree varies within the wide range of from 18.6 to 51.8 per cent. in the wood, while the leaves contain as much as 54 to 65, and some even over 70 per cent. while living; when dry, still 10 to 12 per cent. The wood of deciduous hard woods, like oak, ash, elm, birch, beech, contain in the average 38 to 45 per cent.: soft deciduous trees 45 to 55 per cent., and the conifers 52 to 65 per cent. White pine when young may show as high as 77 per cent. of its weight as water, while larch, of all conifers, has the smallest water capacity, namely, 45 to 55 per cent., ranking with the deciduous soft woods.

This hygroscopic water is reduced by seasoning to 10 or 12 per cent.; this amount being retained even in well seasoned woods.

Given the entire mass of wood and foliage on an acre of forest, an approximative calculation of the total quantity of water contained in the trees will show that 56 to 60 per cent. of the weight of the forest must be attributed to water, while only 44 to 40 per cent. is represented by dry substance. In agricultural crops it is known that the amounts of water are still larger, reaching sometimes 95 per cent. of the whole weight. The production of dry substance in a well-kept dense timber forest may amount annually to from 2,500 to 3,000 pounds per acre, leaving, then, for the hygroscopic water 3,750 pounds, and the chemically fixed water, say, 1,250 pounds; so that for this factor of dissipation 5,000 pounds in round numbers as a maximum will suffice.

ELEMENTS OF CONSERVATION.

In discussing the elements of dissipation as to the degree of their effect under forest-cover compared with the same elements at work in the open field, we have seen that the shade, the low temperature, the relative humidity, the absence of violent air-currents, the water capacity of the forest floor, are all acting as factors of conservation. We have seen that the quantity of water lost by evaporation—the most fruitful source of dissipation—may be more than six times as great in the open as in the forest. There is only one other element of conservation affecting water supplies which requires special mention. This is the retardation in the melting of the snow which is due to forest-cover. According to Dr. Buehler, of Zurich, this retardation in Switzerland amounts to from five to eight days in general, and may, according to weather conditions, be several weeks, thus giving a longer period for distribution. The evergreen coniferous forest in this respect naturally does better service than the deciduous one.

The conservative effect of the forest-cover is especially of value on the western mountain ranges which are liable to be swept by the

chinook, dissipating as if by magic the snow-cover over which it sweeps.

The proposition, then, to remove the forest-cover in order to allow the drifting and compacting of the snow, from which possibly to secure a longer period of distribution even if there were no other objection, must be considered a hazardous and ill-advised expedient.

The influence of the forest upon the condition and drifting of the snow is graphically related by Middendorff in his description of Siberia, speaking of the Buran or snow-storm characteristic of the treeless plains of tundras.

> As far as the forest reaches and impedes the action of the winds the snow lies everywhere evenly and loosely, so that in the beginning of winter one can travel only on snow-shoes. As soon as the tundra is reached there is no need of snow-shoes. The snow lies either like a thin carpet, or drifted together in incredible masses, so compacted as to bear man and beast, etc.

The popular notion which ascribes to the moss-cover or spongy character of the forest floor a conservative function beyond that of retarding evaporation and infiltration seems to be entirely erroneous and needs revision. The idea that the moisture of the soil and the flow of springs is increased by water from the spongy cover is altogether in contradiction to physical laws, and can be shown experimentally to be a mistaken one.

Water filters through the cover by the law of gravitation until the spongy mass has become fully saturated. With an addition of water it will filter through to the soil, as long as the supply continues and the soil is not so saturated that it can not readily absorb any more water. At last, the supply continuing, the cover will refuse to convey it and will shed it superficially, leaving opportunity to reach the soil only where the moss-cover is interrupted. When the water supply ceases, evaporation begins above, and by capillary attraction the cover supplies its loss of water on the surface from the soil below.

To give water to the strata below, it would be necessary that these should have become dry, or at least drier than the moss-cover before the latter had lost its water. This may occur and depends naturally upon the structure and nature of the soil. If the soil is strongly fissured, thus rapidly draining the upper strata, then, if the moss-cover is still saturated and an additional pressure is exerted by water standing or falling on it, a further supply of water may be given up to the soil; if, however, the moss is only just saturated and no further access of water takes place from above, then there is no physical law by which a surrender of this saturation water to the soil could take place as long as the underlying soil is of a gravelly or non-absorbing nature. If its nature is like clay, marl, fine sand, capable of attracting water, then the further process of water absorption depends upon the difference between the water capacity of the cover and that of the soil.

In a sand soil in which the upper strata lose their water rapidly to the lower, the moss-cover, which holds water more tenaciously, can be made to give up water to the soil as long as the capacity for absorption by the sand is greater than the capacity for retention by the moss.

A loam or clay soil takes up water very slowly, but takes up a great deal before it is saturated, and the process of filtration goes on very slowly; if, therefore, a plentiful rain falls, there is formed

under the moss-cover a shallow, nearly saturated layer of soil, which acts as an impermeable stratum. This layer is protected by the cover against rapid surface drying, and since it gives up its water only slowly to the lower strata, it remains moist so long as the moss-cover is not dry. As soon as by evaporation the cover has lost its water, which it does rather rapidly, the soil must give up some of its moisture by capillary attraction to supply the deficiency in the cover. A deficiency of moisture occurring in such soil earlier than in the cover can be presumed only when the water is utilized by the roots and transpired; but as such transpiration water is dissipated and does not increase the run-off, the process can not be considered a conservative one.

These are the extreme cases between which in nature many intermediary conditions occur. The litter cover does not act analogously to the moss-cover or to a sponge. A difference must here be noted between the newly fallen loose litter of the previous year and the closely packed and felted litter accumulations of former years. The former allows a rapid filtration; the latter, according to Riegler's experiments, is nearly impermeable, and the water practically can enter the soil only where the litter is interrupted. The compacted litter serves admirably to retard evaporation. In reality there rarely exists an uninterrupted cover of such litter or a cover of one uniform nature; open spaces, moss-covers, varying thicknesses of litter-cover interchange, and accordingly the water penetrates readily, while the cover performs its duty as a conserving agent against evaporation.

It is, then, *the protection against evaporation alone*, due to greater relative humidity of the forest air, to the shade, to the breaking of the winds, and to the protective soil cover, which *makes the forest a conservator of moisture everywhere*, even where it does not by its peculiar location increase the amount of precipitation.

Springs, then, may be influenced in the amount of their discharge by a removal of the forest; not because the forest supplies them directly with more water, but because by its removal the rate of evaporation is increased.

The total conservative action of the forest with reference to available water supplies, aside from an increase of precipitation, is expressed by the difference between the elements of dissipation and those of conservation; the former comprised in the loss of the water by retention or interception, evaporation, and transpiration, the latter in the protection against evaporation. This balance is known to be in favor of the forest cover in some localities and under certain given conditions; but it will have become apparent that a general statement or quantitative expression of the amount of benefit would be well nigh impossible.

Water supplies remaining available.—As will have appeared from the foregoing statement it is almost impossible to calculate the difference between the precipitation on one hand and evaporation and transpiration on the other. Yet in an ingenious manner a calculation for one of the Prussian mountain districts is proposed by Dr. Weber as follows: Using the figures which are exhibited in the table on page 309 he argues that the amount of water left over and above the amount evaporated in the open at low altitudes, deducted from the amount left over and above evaporation in the forests of high altitudes, will suffice to cover the amount of transpiration; thus, in the spruce forest at the station of Sonnenberg, the surplus of precipita-

tion above the water needed for evaporation had been 1,093.8 millimeters; deducting from this the quantity which was found remaining in the open at Schoo, and which would suffice for purposes of transpiration and plant growth, a balance for drainage of 771.3 millimeters results; for the beech forests at Melkerei and Hadersleben, the calculation gave a balance of 1,176.8 — 495.8 = 681 millimeters for drainage. On the average, therefore, 700 millimeters of the precipitation in the mountain forest in this locality are saved for the "run-off," that is, 100,000 cubic feet of water per acre.

To get a conception of what these 100,000 cubic feet mean in the river flow, it may be stated that with average water level the Rhine above Mannheim has a flow of 47,700 cubic feet per second, an amount which would be yielded by 40,000 acres of mountain forest, provided all water is drained into the river; and to keep the river continually flowing at this rate would require, on the basis of these figures obtained experimentally, a forest area of 23,472 square miles, a calculation which by no means leads to absurd results for practical probability, since the drainage area of that part of the river is in reality about 30,000 square miles, largely in forest.

ELEMENTS OF DISTRIBUTION.

The distribution or "run-off" of the available water supply is almost as important and often a more important factor in the economy of the water than the quantity of available supply itself, and the manner in which this takes place influences considerably the ultimate availability of the supply for human use.

This distribution of water proceeds under the action of two natural forces, gravity and capillarity.

These two forces are acting in opposition to each other, a fact which is often overlooked. Under the action of gravity the water seeks a lower level; the action of capillarity tends to elevate the water. The movement of the water in the soil is therefore a resultant of these two forces, and since gravity remains constant but capillarity is variable according to the structure of the soil, the latter force and the conditions upon which its action depends are the most important factors in determining the nature of the distribution or run-off of the water.

After precipitation has reached the ground its run-off is influenced by surface conditions of the soil-cover, by the structure and stratification of the soil itself, its water capacity, its permeability and other physical conditions; further, its slope and also its liability to disintegration and to form detritus under the erosive action of the water; further, upon the topography of the ground and such elements as modify soil-cover, soil conditions and topography.

There are two methods of distribution or run-off, namely, the superficial or surface run-off, and the underground run-off resulting in springs which eventually change into open runs, brooks, and rivers.

To understand any influence upon the run of water in springs and brooks a brief consideration of the nature and essential features of springs and open runs is necessary.

Springs.—A spring is that place where the water which has penetrated the soil re-appears collected on the surface. Springs are in most cases the beginnings of brooks and rivers. According to the manner in which the percolated water reaches the surface, springs may be classed as standing and running springs.

The standing or ground-water springs are such as collect water in some depression of the soil and overflow only as long as the water reaches the lower level of the outlet. Their formation is easily understood from the accompanying figure (I), in which (1) represents a hill-side of massive rock, continuing under the overlying strata at *a*. The latter consist of impermeable strata (2, 2) (clay, loam, marl); above this

a layer of gravel or coarse sand and rock material (3), and above this a stratum of soil (4), which at X is absent, leaving an open bowl where the gravel layer becomes visible. All the rain-water falling on the plateau *o p* and on the slope *o a* running

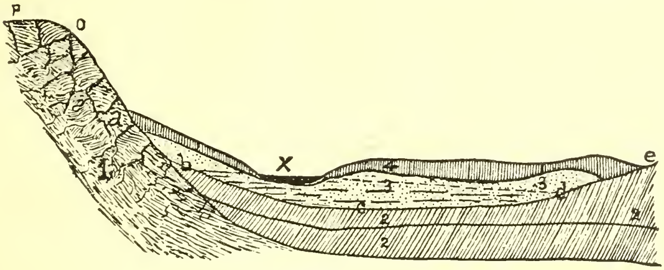

FIG. I.

down, when arriving at the impenetrable strata near *b*, will be diverted into the gravel bed and spread in this, being prevented by the underlying impermeable strata from sinking. When sufficient water is supplied the water level rises until it appears at X, and if there is an outlet over the rim of the bowl and sufficient slope of the ground the spring begins to flow, forming, it may be, the beginning of a brook. Such a standing or ground-water spring ceases to run if precipitation cease for a length of time sufficient to reduce the water level below the outlet. Similar conditions can occur alongside of rivers when the seepage of the river supplies the water to a spring below the river level, and the level of these seepage waters rises and falls, of course, with the rise and fall of the river level.

Of running springs, there may be distinguished, according to the manner of their formation, three kinds—soil or surface springs, fissure springs, and cavern springs.

A surface spring originates when a more or less impermeable soil forms part of or lies near the upper soil stratum, allowing the water to enter only imperfectly and to an inconsiderable depth, and, passing through the looser parts of the soil, to collect and come to the surface at some point where the top soil is absent. These shallow-soil springs naturally vary quite sensibly, according to the physical conditions of the surface, and are dependent directly on the precipitation ; dry up easily if it does not rain or if the soil is exposed to insolation and is deprived of shade; they are warm in summer and freeze out in winter. They are usually found in localities where the rock consists of easily disintegrated clay slates and sandstones, capped with a shallow layer of decomposed rock, or in the neighborhood of loam hills. An addition of broken rock and stones to the soil facilitates the penetration of the water and increases the comparative flow of these springs.

Whole districts along the foot of the Alps in Switzerland, Bavaria, Austria, and the Carpathians in Galicia, etc., have hardly any other kind of springs.

The second class, conveniently called "fissure" springs, originate from waters which have deeply penetrated the soil and rock through the fissures, rents and splits, or numberless cleavage strata of the upper rock formations, and ultimately reach a deeper-lying inclined rock formation, which prevents further penetration and causes

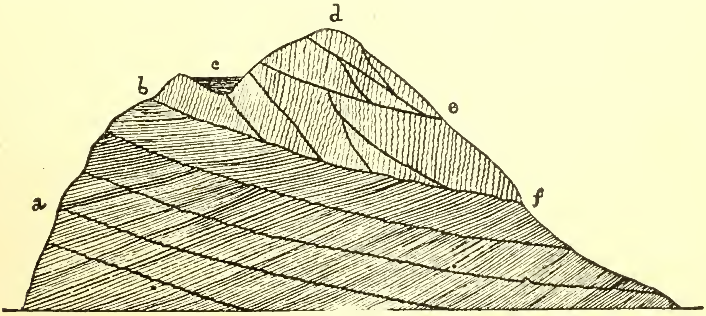

FIG. II.

the water to run along its upper plane until the formation somewhere comes to the surface and with it the collected water of the spring. These conditions are illustrated in the accompanying cut (fig. II), in which *b c d e f* represents the upper fissured

formations through which the rain and snow waters penetrate to the lower impermeable strata below the line *b f*, necessarily gravitating to point *f*, where the opportunity for discharging as a spring exists; a smaller spring might occur at *e*. Such conditions exist where lime or dolomite rocks overlie hard sandstones, compact clay slates, or clay beds. These springs, as a rule, are much less dependent on the changes of precipitation and temperature; they are mostly continuous and even in their flow and their temperature.

The third class of the running springs may properly be called "cavern" springs, from the fact that while their waters are drained like those of the second class, they are first collected in some subterranean basins or caverns, and appear on the surface as overflow of these basins.

In the accompanying figure (III), *a b c* is the catchment basin, from which the vari-

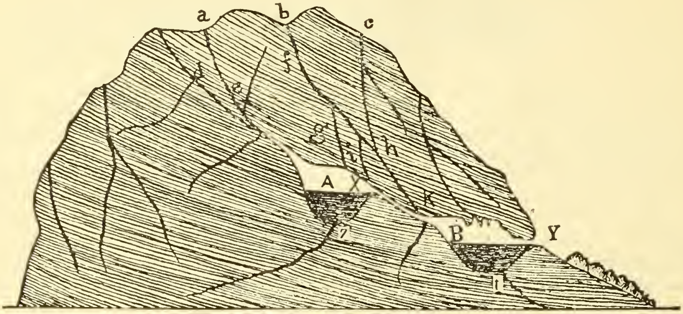

FIG. III.

ous fissures conduct the water to *A*, overflowing at *X* into *B*, and from there overflowing and appearing at the surface at *Y*.

This kind of spring is found frequently in limestone formations, and since the water of such often come from great distances from above their discharge at the surface, they are usually of very cold and even temperature; they are apt to run low when the soil is frozen and when precipitation is small, and their discharge is more or less intermittent. The obstruction of the old and opening of a new outlet by a fall of rocks at *X* and *Y*, and the widening of a formerly insignificant fissure at *z* or *t*, may reduce the flow or stop the original spring entirely, opening a new one in an entirely different part of the locality.

While we have here considered conditions under which springs are formed, there are also conditions under which their formation is excluded; such might be found in extended plains or low hill lands, with a compact, impermeable soil which may give rise to pools and morasses but not to springs. Plateaus of fissured limestone dolomites or of compact gneisses or granites may also be poor in springs, their waters sinking at once to such depths that no discharge is met in the immediate neighborhood of the catch-basin, or else shedding the water at once superficially.

The object of this elementary explanation of the formation of springs is to show that geologic conditions to a large extent influence the manner in which the waters falling on a certain territory are collected and discharged or distributed in underground channels, and that, in spite of favorable forest conditions, a region may be poor in springs and without any disturbance of the forest cover a change in the run of springs may occur.

The water of the springs finally flows off in open runs, brooks, rivers, and lakes to the sea. Besides, there is a certain amount of water running off the surface without first penetrating the soil or having been collected in springs; this run-off takes place during precipitation and melting of snow, finding its way through smallest furrows in the soil surface, or directly over the surface and slopes in trackless courses into the open runs.

These are the waters which occasion the dangerous floods, which fill the channels that were dry before, and give rise to so-called

torrents, to freshets, and to a great waste of available water supplies by the rapidity with which they are collected and carried off.

The watercourses which rely on this source of supply must naturally differ from those supplied by springs in the uncertain change and fitful state of their water conditions.

Between these two main types of "run-off" there are intermediary types, which supply themselves by both methods in varying degree; a stream may begin as a torrent and later in its course find additional supplies from springs, or the reverse may take place—being originated by a spring it may have no other additions except from the superficial run-off. It is evident that the conditions for a superficial run-off are to be found, first, in the amount and nature of precipitation, and next in the soil and surface conditions.

A violent rain-storm will naturally furnish more superficial run-off than when, the rain falling slowly, time is given for the soil to absorb it; a snow-cover fallen on frozen ground is apt when melting to shed its water over the frozen surface without penetrating the soil.

Nature of soil and soil-cover and topography determine, with equal amounts of water to dispose of, what the nature of the run-off will be. An impermeable soil takes up sufficient water to make it plastic and then sheds all additional water superficially; a permeable soil continues to take up water and conducts it into the depth. This difference of behavior must influence and determine largely the conditions of any river-bed; for if it run for some distance through impermeable soil, even insignificant rain-falls will rapidly collect and swell the river, while the permeable soil would have taken up and held all or parts of the precipitation and would only gradually have given it up.

Since the amount of superficial run-off is in inverse ratio to the amount drained off by springs, it follows that, where superficial drainage is the rule, the supply to springs is scanty, and *vice versa*.

The topography determines the rapidity of run-off and of collection. The more diversified the country—cut into dells, coves, rills, and furrows, steeper and less steep slopes—in the greater number of runs of unequal length is the water collected, while the less diversified the contour the more water must be carried off in each run. Yet where the diversity of configuration is accompanied by steep slopes the run-off may be so rapid that the valley river is filled more rapidly than the river of the open plains country with even slopes of moderate inclination.

Thus in some of the river valleys of West Virginia the water-sheds are scooped out into such an array of coves, gashes, and water-courses and minor water-sheds, and so steep and rapid in descent that, in spite of the forest cover, a rain-fall of a few days will induce a rapid rise of the rivers, while the same amount of rain will hardly wet the ground in a prairie country like Iowa.

As regards soil and surface conditions it is obvious that the less permeable the soil or soil-cover the less the absorptive capacity of the same, and the fewer mechanical obstructions are met the more water runs off superficially.

An additional factor in determining the nature of superficial runs is the amount of rock material and soil which they carry. Since this detritus is deposited wherever the velocity of the water sinks below that necessary to carry it, forming sand-banks and rubbish-heaps which obstruct and change the direction of the run, it plays quite

an important part in shaping the bed of the river, besides influencing the whole system of dependent brooks and rivers. And in this the nature and shape of the detritus—whether fine sand or earth, smaller or larger rock masses, stones, roundish, square, or flat—cause much difference; and this in turn depends upon many conditions, geological and climatical.

According to the nature of the rock from which it is derived, the detritus appears in different shapes, which again changes in form during its further transportation by the waters in different ways, and therefore exerts a varying influence upon the run. Thus the detritus, which appears in large plates or shales, is carried more easily than the square or round rocks; the former, even when deposited, hinders the flow of water between the plates but little, and therefore gives less cause for stow-water than the heavy square rocks, which resist the transportation and obstruct the flow more effectually.

Sand and gravel detritus is easily carried, easily accumulated, and again with a new flood easily removed; it offers, therefore, little resistance to the flow of water, but becomes objectionable in filling the lower channels of rivers, etc.

Clay detritus, although easily carried, is apt to compact and cement the rock detritus together, and thus becomes one of the worst impediments of water flow and is the cause of the worst dangers from flood waters.

From these examples it is apparent that two rivers, although under similar conditions of rain-fall, physical conditions of soil and topography, may yet have a different behavior, according to varying character of the detritus.

As to the amounts and nature of precipitation we must keep in view rainy and rain-poor localities, short and insignificant rains, short but violent, long and mild, or long, plentiful rains; also periodical, seasonal rains and irregular rain-falls. The effect of these differences in the nature and time of occurrence of the rain-fall must naturally affect the nature of the run-off. The effect is still further complicated when the precipitation is partly snow, when not only the mass of accumulated supply but also the progress of melting determine the result of the run-off.

Therefore we find based upon this one factor, namely, the nature and time of occurrence of precipitation, differences in the run-off which are dependent upon differences in climatic conditions. Thus tropical rivers show one or two regular high stages of water according to whether they have one or two rainy seasons; in regions of equinoctial rains a spring and fall freshet is normal, while the rivers may be almost dry in summer or winter; the frequent thunderstorms in the mountains of Switzerland produce short but rapid floods during the summer, while the fall is characterized by low water in the rivers. This climatic difference in water-flow it is important not to forget when discussing the influences which may modify the discharge of waters.

With these premises as to the general nature and conditions of run-off we can now discuss the variable influences which may change or modify the manner of distributing the water though springs and open channels.

In general, the amount of water in springs and open runs depends on the area of the catch-basin; *i. e.*, the area from which the precipitation is drained into the springs or runs, and further on the amount and frequency of the precipitation; but the manner of its disposition

and its distribution, as we have seen, depends mainly on conditions of soil and soil-cover.

On a given territory with given geological, topographical, and climatic conditions, the only directly variable conditions are those of the upper soil-strata and of the soil-cover.

We are interested, therefore, mainly in determining not only the water capacity of soils and soil-covers, but also the intensity of their water absorption and the amounts of water which are drained through them in given times. We are interested in studying by what means the draining capacity of the soil is increased, and by what means altogether the run-off may be changed in its nature from a superficial to a subterranean one and the reverse.

Unfortunately the material for the discussion of these points is still meager and unsatisfactory.

The water capacity of soils and soil-covers in general has been referred to as an element of interception. With reference to the run-off, this capacity becomes influential in determining the manner of run-off. As soon as the soil-cover and the upper soil-strata are saturated, and especially when the latter are impermeable and the rain continues, either no water or only a small part gradually can find entrance into the soil, and the run-off becomes superficial, or, if the ground be not sloping, stagnant water results.

For every forest there is, therefore, a time when the superficial run-off would be no more impeded than from an open field of similar conditions but for the retardation by the trunks, underbrush, and roots. This time, however, occurs later in the forest than on the unforested and especially naked soil, because the water capacity of the soil-cover as well as of the protected soil is greater than that of the naked soil or that covered with field-crops.

In addition to the experiments in this respect cited on page 305, we give the following results of the experiments of Dr. E. Ebermayer, which refer to the amount of water contained in a heavy loam soil under a forest of spruce twenty-five, sixty, and one hundred and twenty years old, and a naked soil at 16-inch (40 centimeters) and 32-inch (80 centimeters) depth.

Water contents of a loamy sand; results by seasons expressed in percentages of the weight of the soil.

Season.	Spruce.									Naked soil.		
	25 years old.			60 years old.			120 years old.					
	16 inch.	32 inch.	Average.	16 inch.	32 inch.	Average.	16 inch.	32 inch.	Average.	16 inch.	32 inch.	Average.
Winter (January and February)	20.23	17.00	18.61	18.06	17.76	17.91	19.75	22.44	21.09	19.96	24.73	22.35
Spring (March to May)	18.62	18.02	18.32	15.29	16.28	15.78	17.47	20.83	19.15	20.66	20.51	20.58
Summer (June to August)	15.10	16.22	15.96	14.42	17.03	15.72	17.78	20.90	19.97	19.97	19.98	19.97
Fall (September to November)	16.57	17.57	17.07	13.49	16.52	15.00	14.88	19.46	17.17	20.04	20.20	20.12

These figures show that a loam soil under forest cover is apt to be drier in the depth of the root-region than in the open field, less so under an old and scattered growth than under a younger growth or thicket, and that at all seasons.

A repetition of these experiments, in which depths from the top to 32 inches were included, gave during two years the following averages of water capacity, expressed in percentages of the weight of the soil:

Averages of water capacity, expressed in percentages of the weight of the soil.

Depth.	Spruce. 25 years old.	Spruce. 60 years old.	Spruce. 120 years old.	Unshaded soil.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
0 to 2 inches	30.93	29.48	40.32	22.33
6 to 8 inches	19.19	18.99	19.30	20.62
12 to 14 inches	19.10	16.07	18.28	20.54
19 to 20 inches	18.40	16.26	20.16	20.14
30 to 32 inches	17.91	17.88	21.11	20.54
Average	18.65	17.30	19.71	20.46

Ebermayer combines the values for depths from 6 inches down to 32 inches, and then concludes that the forest soil is less moist, due to the transpiration of water by plants. This conclusion is, however, not at all warranted. For if one combines the figures found in all the strata from top to 3 inches down, they figure as follows: Spruce twenty-five years old, 24.79 per cent.; spruce sixty years old, 23.39 per cent.; spruce one hundred and twenty years old, 30.01 per cent.; naked soil, 22.39 per cent.

Hence, take it altogether, the naked soil contains considerably less water than the forest-covered soil. But the distribution of the water through the different layers of the soil is different in the two cases; the naked soil, due to rapid evaporation no doubt, contains the least amounts in its upper strata, where the forest soil with its absorptive cover preserves the largest amount. Measurements of the stratum from 2 to 6 inches would probably have shown the preservative effect still more prominently.*

Nor is the further conclusion of the eminent author warranted, that this condition of things necessarily influences the effect of forests on springs. This is more dependent on the porosity of the soil, due to the mechanical protection which the soil-cover offers against the compacting effect of raindrops and to the numberless channels which growing and decayed roots offer to conduct the water into the depths.

In regard to the water supply of springs, Ebermayer maintains that the forest reduces it more than uncultivated naked soil but less than meadows and uncultivated fields, but that the forest has great significance for the preservation of existing springs. Therefore, extensive deforestation will result in reducing the supply to springs, because the deforested soil covers itself soon with grasses and weeds, which require more water and furnish less drain-water than the forest.

* How much water the soil-cover can contain appears from the following measurements of Dr. Ebermayer: On the 17th of August, 1885, after rainy weather, the moss-cover in a sixty-year-old spruce growth contained 72.33 per cent. at the top; 76.64 per cent. on the lower side, and 71.67 per cent. in the humus soil beneath.

After a rain-storm lasting one and a-half days, on September 9, 1885, the moss-cover contained 80.45 per cent. at the top; 74.61 per cent. on the lower side, and 74.42 per cent. in the top soil.

Of still more importance for the run-off than the water capacity is the water conductivity of the soil, or, as I should call it, the intensity of water absorption.

The rapidity with which the water is conducted from above downward must necessarily influence the nature of the run-off.

Gravity tends to drain the water downward, capillarity to carry it upward; the difference of these two forces in the main must, besides the mechanical obstructions of the soil particles, determine the rapidity of drainage. Experiments to establish the rate under various conditions are very few and unsatisfactory.

The capillary conduction from below has frequently been made the subject of investigation, but the downward movement has not yet been studied with sufficient detail, and it has hardly yet been recognized by the experimenters that this depends upon the difference of gravity and capillarity as two opposed forces.

Accorning to E. Wollny's experiments in 1883 and 1884—

(1) Water is conducted downwards the more rapidly the larger the soil particles (*i. e.*, the less capillary attraction exists).

(2) The non-capillary interstices of the soil accelerate the downward movement of the water (*i. e.*, the less mechanical obstruction of soil particles).

(3) In granular soil the water penetrates faster than in powdery soil (*i. e.*, penetration is the slower the denser the stratification). It is most rapid in quartz and slowest in clay; in humus at a rate between these two, but in a mixture of clay soil and humus faster than the average of the two.

(4) The rapidity of drainage in a granular soil is independent of the size of the grain.

The experiments were made with soils of varying grain in tubes 110 centimeters deep, the water dropping on top constantly; the results are exhibited in the following two tables:

Water conductivity in soil with varying size of grain.

Soils.	Water sank to a depth of— After 5 minutes.	After 10 minutes.	After 15 minutes.	After 25 minutes.	After 45 minutes.	After 65 minutes.	After 120 minutes.
In soil of grain:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
0.01 to 0.071 millimeters	8.8	12.8	16.2	21.3	30.0	36.7	52.0
0.071 to 0.114 millimeters	18.0	27.0	37.0	52.5	79.0	103.0	....
0.114 to 0.175 millimeters	28.3	48.0	65.0	96.0	....	....	....
0.175 to 0.2 millimeters	45.0	82.0	110.0	....	....	....	....
0.25 to 0.50 millimeters	84.0	....	....	....	....	....	....
Mixture of various grains	11.0	19.0	24.5	33.2	50.8	65.5	106.0

Water conductivity in granular soils.

Soils.	Water sank to a depth of— After one-half hour.	After 1 hour.	After 3 hours.	After 4 hours.	After 23 hours.	After 59 hours.
Loam powder:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
0 to 0.25 millimeters	9.0	12.1	20.2	23.4	57.4	97.6
0.5 to 1.0 millimeters	18.8	32.1	82.4	100.0	....	....
Loam granules:						
1 to 2 millimeters	19.0	32.2	83.1	100.0	....	....
2 to 4 millimeters	19.3	32.0	81.5	100.0	....	....
4 to 6.75 millimeters	18.8	30.4	77.5	99.6	....	....
6.75 to 9 millimeters	18.5	31.0	80.5	100.0	....	....
Mixture	4.0	8.0	11.0	19.5	24.1	100.0

According to Fesca the downward movement proceeds quickest in a dry dust, only slowly in clay soils; the same amount of water being drained through the former in one hour which it took two days to drain through the latter.

The influence of a soil-cover on the condition of soils was investigated directly by Wollny; he comes to the result that vegetation and cover with dead material (straw, litter, etc.) tend to preserve the loose granular structure of the soil.

Now, since the forest cover has a tendency to preserve the granular porous structure of the soil, which is favorable to filtration, and as moreover the roots furnish channels for unimpeded drainage, it must have the tendency, other things being equal, to allow a more rapid filtration than the naked, mostly compacted soil. The temperature too appears to have an influence favorable to rapid filtration in the forest, for, according to Pfaff, in the field during winter three-quarters of the precipitation will sink to 2 feet depth in the soil, and not more than 10 to 30 per cent. in summer.

Unless, therefore, the forest cover itself had a tendency to retard penetration, which we will see is not the case, the influence of the forest upon the intensity of water absorption would be in the direction of diminishing superficial flow.

This factor is of the utmost importance in the discussion of the causes of floods. Without a consideration of the water capacity, and still more of the intensity of water absorption, it will never be possible to draw conclusions as to probable floods from the amount of precipitation alone.

The influence of various soil conditions and soil-covers upon the amount of water that will filter through has been investigated by Wollny and Ebermayer in an extended series of experiments.

Experiments of this kind which will yield results applicable to natural conditions are exceedingly difficult to arrange, and require not only many precautions but must be continued for a long time before generalizations can be attempted. One of Wollny's series of experiments attempted to show the influence upon filtration of a grass-cover on different soils. The results calculated for an acre are as follows:

Kinds of soil.	Amount of filtration.	
	Fallow field.	Grass covered.
	Pounds.	*Pounds.*
Calcareous sand with humus	1,593,216	782,334
Quartz sand*	3,044,250	661,548
Loam soil*	1,529,671	59,105
Peat soil	2,048,124	405,162

*From May to November.

The grass-cover, therefore, reduced considerably (by 50 per cent. and more) the percolation of water. Ebermayer experimented with boxes 43 square feet surface (4 square meters) and 4 feet deep, filled with fine garden soil, leaving one bare, covering another with moss and two others each planted with six-year old plants of beech and of spruce, with the following results arranged according to seasons:

Year.	Rain.	Filtration water in height—			
		Under beech.	Under spruce.	Under moss.	Naked soil.
1886.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
March to May	156.98	12.65	10.52	16.96	10.93
June to August	560.22	15.89	12.09	31.60	26.13
September to November	114.45	1.12	0.76	7.17	3.27
December to February	126.30	9.73	5.98	11.40	9.08
Total	957.95	39.39	29.35	67.13	49.41
1887.					
March to May	219.20	10.61	5.05	14.40	9.97
June to August	210.60	2.50	1.49	13.00	3.91

In these experiments it is remarkable how small a percentage of the rain-fall was filtered through, which would lead us to look at the results with caution, namely: Of the total rain-fall was filtered—

	1886.	1887.
	Per cent.	*Per cent.*
By soil covered with moss	7	6.2
By soil naked	5.1	3.5
By soil covered with beech growth	4.1	2.9
By soil covered with spruce growth	3	1.5

In regard to the amount of filtration which various soil-covers allow, we have the following very instructive results from the experiments of Wollny, in which the amounts of rain and corresponding filtration on 62 square inches surface are given:

	May to September, 1886 — total rain 28,529 grams.		April to September, 1887—total rain-fall 18,652 grams.	
	Amount, grams.	Per cent. of rain-fall.	Amount, grams.	Per cent. of rain-fall.
Oak leaves:				
5 centimeters	17,591	61.7	7,894	42.3
10 centimeters	19,482	68.3	7,353	39.4
20 centimeters	21,160	74.1	12,954	69.4
30 centimeters	21,061	73.8	13,272	71.2
Spruce litter:				
5 centimeters	17,793	62.4	8,653	46.4
10 centimeters	19,277	67.5	7,356	39.4
20 centimeters	19,523	68.3	14,611	78.3
30 centimeters	19,467	68.2	13,912	74.6
Pine needles:				
30 centimeters	19,734	69.2	9,784	52.4
Moss:				
5 centimeters	14,993	52.5	7,260	38.9
Bare soil:				
30 centimeters	11,610	40.7	3,636	19.5

These figures show that a litter will filter considerably larger amounts of water than a soaked soil of the same depth, and that the moss cover allows less water to filter than the litter. This is accounted for by the soil needing a larger amount of water to supply the moisture evaporated than the litter which remains moist.

Notable is the influence which the thickness of the cover exerts upon the amounts of drain water and also the relation of the amount of precipitation to the amount of filtration.

It will be noticed that with a thicker cover to 1 foot in depth (30 centimeters) the amount of precipitation hardly changes the amount of drain water, while the lighter covers have much less power to preserve a small precipitation, for of course the amounts not drained are evaporated.

We come then to the conclusion that a forest floor, although retaining much of the water in its upper strata, renders the soil more permeable and therefore allows less water to run off superficially.

With regard to the superficial run-off, without any evidence furnished by experiments, we can at once understand that it is impeded by any kind of mechanical obstruction, such as is offered by the vegetation of a meadow or of a forest.

The great number of inequalities which the forest floor offers in addition to the trunks and stumps and fallen trees subjects the run-off to many detours; thus retarding its flow and its collection in the open runs and brooks. This retardation is increased by the mechanical obstruction which the crowns of the trees exert upon the rain-fall. Every leaf, every twig breaks the force and retards the fall of

the raindrops, allowing those fallen before to penetrate the soil. And although, as we have seen, the amount of water which is thus lost to the soil is by no means as large as has been believed (see p. 305), the devious ways in which it reaches the soil makes the flow of water from a forest-covered hill longer in time than if the rain had fallen on a bare slope.

This mechanical effect is further favorable to the penetration of water into the soil, as it prevents the rain from compacting the soil; preserving thereby the mellow condition of the soil, which is destroyed on the open field by the force of the raindrops. It also allows more time for the absorption of water by the soil.

There is, in fact, no influence of the forest of more moment in the distribution of the available water supplies than the mechanical retardation of the "run-off," while in the conservation of supplies the retarding influence upon evaporation is the potent one.

There occurs, to be sure, as the result of long-continued precipitation, a stage when the run-off is hardly more impeded by the forest than it would be under the same conditions by an unforested slope, but this stage occurs in the forest *later* than on unforested soil and later still than on naked soil.

Still more effectual and beyond all dispute is the office of a forest cover in averting or diminishing the torrential action of water in carrying and depositing the debris or detritus in its course, and, as we have seen, the detritus affects the nature of the run-off considerably, narrowing the channels, filling the river beds, causing stowage and floods in the mountain valleys and upper river systems.

The history of the mountain torrents in southern France has proved, if proof were needed, not only the effects of deforestation, but also that reforestation of the denuded hills is the only proper remedy for the regulation of these torrents.

We can not go into the discussion here of the effect which the forest influence upon the head-waters causes in the water conditions of the rivers, since it can not be done briefly, local and purely meteorological conditions giving rise to many differences.

I can point out only a few considerations affecting this discussion, which are apt to be overlooked.

In dry times the retention of the waters by the forest may affect the river flow unfavorably, although for a time the protection which it furnishes against evaporation may keep up the supply more continuously. Whether this conservative effect outbalances the former retentive one depends on local conditions. During ordinary rainy seasons, without excessive rain-falls this effect of a forest cover will act as a regulator of the run-off, and therefore of the river flow.

In seasons of abnormal rain-falls the regime of rivers will show different behavior in different parts, according to differences of condition at the head-waters, the middle, and the lower course.

The first cause of abnormal floods is the occurrence of abnormal rain-falls or the sudden thawing of abnormal masses of snow. If the former occur after the soil has been saturated, or the latter when the soil remains frozen, the forest cover will be powerless to influence the run-off and will shed the water as rapidly almost as the open ground, although even the brief retardation of the confluence of water masses which the obstacles of a forest growth cause, may, under certain circumstances, become important.

But in its further course the drainage of this water, collected in the runs, is favorably influenced by the presence of the forest, it hav-

ing prevented the formation and deposition of detritus in the river bed.

In the main river, which consists of the confluence of many affluents, the effect of flood waters depends almost entirely upon the comparative lengths of the affluents, or rather on the simultaneous or non-simultaneous arrival of the flood waters. A deforestation in one of the side valleys may, therefore, be an advantage or it may be a disadvantage, while a retardation of the total flood, which can only be for a few hours, would be of no account in the main river.

An interesting note as to the amount of retardation which may be produced by the artificial means employed in the French Alps for regulation of water-flow, namely, forest-planting in connection with overflow dams, is given in M. Mathieu's work on "Reboisement in France."

The two basins of Faucon and Bourget were visited by a terrible downpour of rain of twenty-five minutes' duration. In the upper mountains there fell 42 millimeters, in the lower regions 12.3. The torrent of Faucon (which was in a devastated, deforested condition, but otherwise topographically similar to that of Bourget) was at once filled with flood waters which were estimated to consist of 60,000 cubic meters of water and 180,000 cubic meters of rock material or detritus, the flood subsiding in two hours.

In the torrent of Bourget, which had been reforested and corrected in its bed, a simple, somewhat turbulent run of water was observed, which at the overflow reached the height of 45 centimeters (18 inches) and lasted about three hours. The report continues:

> These facts show the importance of the forest cover. Thanks to the dense forest growth planted, the flood waters, divided in numberless runs and retarded constantly in their movement over the declivities in the upper basin, arrive only successively and little by little in the main bed, instead of those formidable masses of water and débris which rapidly agglomerated rush into the channel; the brooks called to replace the torrents receive only pure water; flood waters flowing off gradually and made harmless by the regulation of the torrent bed and of the slopes.

The beneficial influence of the forest in case of abnormal floods can then probably be claimed only in so far as it protects the slopes against abrasion and the formation of debris or detritus with which the upper head-waters are filled, and which carried down into the rivers give rise to sand-banks and changes in the river-bed which may affect the next flood.

We may now attempt to summarize briefly what can be said of the influence which a forest cover may be expected to exert upon the distribution of available water supply or the run-off.

In regard to springs.—The moss or litter of the forest floor retains a large part of the precipitation and prevents its filtration to the soil, and thus may diminish the supply to springs. This is especially possible with small precipitations. Of copious rains and large amounts of snow water, quantities, greater or less, penetrate to the soil, and according to its nature into lower strata and to springs. This drainage is facilitated not only by the numerous channels furnished by dead and living roots, but also by the influence of the forest cover in preserving the loose and porous structure of the soil.

Although the quantity of water offered for drainage on naked soil is larger, and although a large quantity is utilized by the trees in the process of growth, yet the influence of the soil-cover in retarding

evaporation is liable to offset this loss as long as the soil-cover is not itself dried out.

The forest then *may* not permit larger quantities of water to drain off underground and in springs, but it can influence their constancy and equable flow by preventing loss from evaporation.

In regard to surface run-off.—Small precipitations are apt to be prevented from running off superficially through absorption by the forest floor; on larger falls of rain topographical and soil conditions have eventually more influence in this respect than the forest floor; regions with steep declivities and impermeable soil will shed the waters superficially in spite of and over the forest floor as soon as the latter is saturated.

The influence of the forest on such waters is to retard their movement over the surface and to prevent their rapid collection into runs. By preventing the formation of detritus and carrying off debris, the disturbances in the open runs below are prevented or abated.

Upon the water flow of rivers and streams which move outside these mountain valleys with lesser grades the forest along their banks has but little influence; but at the headwaters the influence may be considerable by retarding the collection and arrival of waters in the main river-bed, and thus reducing the danger of the flood.

B. E. FERNOW.